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Marilyn Sharp, Joseph J. Knapik, Lolita Burrell, Diane Pietila, Mary S. Lopez, Donald Goddard, Peter N. Frykman, Leila Mouneimneh, Bradley C. Nindl

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Military Performance Division
US Army Reserach Institute of Environmental Medicine
42 Kansas Street
Natick, MA 01760-5007

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13. ABSTRACT *(Maximum 200 words)*

The purpose was to determine the capability of Light-Wheel Mechanics (63Bs) to perform physically demanding 63B tasks. 144 Soldiers participated in this study with a mean (SD) age of 25.5 (5.9) years, height of 175.2 (7.5) cm, and weight of 80.0 (13.4) kg. The tasks were replacing a tire (TR), batteries (BR), alternator (AR), and starter (SR). Strength of the handgrip, back extensors, knee and elbow flexors and extensors, shoulder flexors, lifting strength and bench press strength were measured. Task times ranged from 10.7 (3.8) min for BR to 15.8 (7.3) min for AR. Rating of Perceived Exertion (RPE) ranged from 10.0 (2.1) for AR to 13.9 (2.5) for SR. Except for 12 Soldiers on SR, all were capable of performing all tasks. While many correlations between task performance and descriptive variables emerged, they were quite low. These low correlations provide little direction in developing physical training programs, and may indicate that the current program meets the Soldiers' needs. Factors most associated with 63B tasks were related to experience (rank, age, and time in MOS). The difficulty in developing prediction equations highlights the need to use job tasks to evaluate Soldier performance. It is imperative that experienced mechanics be retained through administrative measures, such as promotion and re-enlistment bonuses.

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USARIEM TECHNICAL REPORT T07-07

JOB PERFORMANCE AS A FUNCTION OF PHYSICAL FITNESS AMONG MOS 63 B, LIGHT-WHEEL VEHICLE MECHANIC

Marilyn Sharp[1]
Joseph J. Knapik[2]
Lolita Burrell[1]
Diane Pietila[1]
Mary S. Lopez[2]
Donald Goddard[2]
Peter N. Frykman[1]
Leila Mouneimneh[1]
Bradley C. Nindl[1]

[1]Military Performance Division
U.S. Army Research Institute of Environmental Medicine
Natick, MA 01760-5007

[2]US Army Center for Health Promotion and Preventive Medicine (USACHPPM)
Aberdeen Proving Ground, MD

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BACKGROUND

This research effort supports a milestone under Army Technology Objective (ATO) S, Enhanced Physical Training with Reduced Injury: Provide a method to assess levels of physiological strain and develop guidance for use in predicting increased susceptibility to injury during training programs. For many years there has been discussion concerning the ability of Soldiers to perform the physically demanding tasks of their military occupational specialties (MOS) (1). Anecdotally, commanders and senior NCOs report that some Soldiers are not capable of performing the physically demanding tasks of their jobs. In addition to anecdotal information, physiological and survey data exist that support the potential for a mismatch between a Soldier's physical capacity and the physical job demands. The actual percentage of Soldiers capable of performing the physically demanding tasks of their assigned job has not been well quantified for any MOS (2). This report will address the issue of strength and job performance in a group of 63B Light-Wheel Vehicle Mechanics.

This project was a collaboration between the US Army Center for Health Promotion and Preventive Medicine (USACHPPM), MD and the US Army Research Institute of Environmental Medicine (USARIEM). The USACHPPM Ergonomics Division conducted the job analysis and identified the most physically demanding, most frequently occurring tasks performed by 63B Soldiers at Ft Bragg (24). The CHPPM Epidemiology Division examined the baseline injury rates for all 63B Soldiers stationed at Ft. Bragg for one year prior to the conduct of this study (19) and for one year following the conduct of this study (20).

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The 144 Light-Wheel Vehicle Mechanic Soldiers stationed at Ft. Bragg who participated in this study. The supervisors who allowed Soldiers time for briefings and participation. LTC Johnson, 82nd Airborne Surgeon, Ft. Bragg, NC, who assisted with the medical clearance of women and followed up on medical questions that came to light during testing. Finally, our sincere thanks to MG George W. Weightman, who wrote a letter to the Commanding General of the 18th Airborne Corps asking for support in providing volunteers, and for a motor pool testing area for the study.

EXECUTIVE SUMMARY

The purposes of this study were 1) to determine the capability of a representative sample of Light-Wheel Vehicle Mechanics (63B) to perform tasks specific to their military occupational specialty (MOS); and 2) to evaluate the relationship between Soldiers' muscular strength and body composition and performance on physically demanding 63B tasks. The Light-Wheel Vehicle Mechanic MOS was selected due to high-reported injury and hospitalization rates, high physical demands, and an adequate number of men and women in the MOS for study. The study was conducted at Ft. Bragg, NC in cooperation with the US Army Center for Health Promotion and Preventive Medicine (USACHPPM), Aberdeen Proving Ground, MD. This research effort supported a milestone under Army Technology Objective (ATO) S, Enhanced Physical Training with Reduced Injury.

The physically demanding 63B tasks selected were based on a job analysis conducted by the Ergonomics Group of USACHPPM. 135 male and 9 female active duty Soldiers (E7 and below) assigned to 63B or 63S slots at Ft. Bragg were recruited to participate in this study. The Soldiers performed four tasks to evaluate job performance: changing a tire, replacing the batteries, replacing the alternator, and replacing the starter of a High-Wheeled Multipurpose Motorized Vehicle (HWMMV). Strength testing was conducted to comprehensively characterize the musculature most involved in the tasks. Isometric strength of the handgrip, back extensors, knee flexors, knee extensors, elbow flexors, elbow extensors, and shoulder flexors was measured. Floor to shoulder lifting strength was measured on a weight stack device, and bench press strength was measured using an Olympic style bar bell and bench. Dual energy X-ray absorptiometry was used to assess body composition. The Soldiers completed questionnaires regarding their physical activity and the physical demands of their MOS, and self-rated their task performance

The Soldiers who participated had a mean (SD) age of 25.5 (5.9) years (men=25.5 (6.0), women= 25.4 (4 3), height of 175.2 (7.5) cm [men=176 1(6.6), women=161.7 (6.2)], weight of 80.0 (13.4) kg [men=80.8(13.1), women=67.5 (11.4)], and a percent body fat of 20.2 (6.8)% [men=19.4(6.1), women=32.0 (5.7)]. The average time in the MOS was 3.3 (1.3) years [men=3.2(1.3), women=3.6 (1.3)]. These Soldiers tended to have strength scores slightly lower than those of infantry Soldiers of similar age, but approximately equal to Soldiers completing initial entry training. The female to male strength ratio ranged from .52 for bench press to .67 for elbow flexion strength. The total time to complete the tasks (with rest times removed) ranged from 10.7 (3.8) min for the battery change to 15.8 (7.3) min for the alternator change. Ratings of Perceived Exertion (RPE) ranged from 10.0 (2.1) for the alternator task to 13.9 (2.5) for the starter task.

Of the 15 women and 290 men briefed to participate in this study 9 women and 135 men were ultimately tested. This smal sample of women cannot be considered representative of all women 63Bs and this is a limitation of the study. Nearly all the men and women that participated were capable of performing the four physically demanding

the starter replacement task. There were no significant differences in any of the strength or body composition measurements made between those who completed and those who did not complete the starter task. Women took longer than men to perform the battery and tire change tasks, but did not report a greater overall RPE. It is unfortunate that we were unable to brief and recruit a larger sample of women, however, the results are encouraging in that women were successful in completing most of the tasks.

The factors most highly associated with successful task performance were related to experience (rank, age, and time in MOS). While many significant correlations between task performance, strength, APFT scores, and descriptive variables emerged, they were quite low. These low correlations provide little direction as to the best way to develop training programs for 63Bs, and may in fact indicate that the current program is meeting the needs of the Soldiers. The alternator tasks tended to have fewer and different relationships with the strength and APFT variables than the other tasks, indicating different physical requirements for successful performance. The lack of strong predictive relationships between strength, body composition, and mechanics task performance was surprising. It is possible that this relatively small sample was not representative of the population as a whole, or that the metric for performance evaluation was not adequately discriminatory. The predictive equations developed using multiple regression analysis did not account for enough variability in task performance and should not be used to select skilled mechanics.

The difficulty in developing prediction equations for the mechanic task performance measures highlights the need to use the actual job tasks to evaluate Soldier performance The best predictors of performance were related to experience. Therefore, it is imperative that experienced mechanics be retained through administrative measures, such as promotion and re-enlistment bonuses.

INTRODUCTION

For many years there has been discussion questioning the ability of Soldiers to perform the physically demanding tasks of their military occupational specialties (MOS) (1). Anecdotally, commanders and senior NCOs report that some Soldiers are not capable of performing the physically demanding tasks of their jobs. In addition to anecdotal information, physiological and survey data exist that support the potential for a mismatch between the Soldier's physical capacity and the physical demands of their MOSs. The actual percentage of Soldiers capable of performing the physically demanding tasks of their assigned MOS has not been well quantified (2).

Army Pamphlet 611-21 rates the physical demands of each MOS, placing them into one of five categories based on lifting demands (11). 16% of entry-level jobs are in the "heavy" category (lift 100 lbs occasionally and 50 lbs frequently), and nearly 50% are rated "very heavy" with lifting demands that exceed 100 lbs occasionally and 50 lbs frequently (38) In a recent study of basic trainees, Soldiers were evaluated as qualified or unqualified for their assigned MOS based on their lifting strength. Nearly all Soldiers (100% of men [n=182] and 96% of women [n=168]) had a one repetition maximum (1RM) lifting strength that was equal to or greater than the *frequent* lifting standard for their job. However, 99% of men and only 51% of women met or exceeded the heavier or *occasional* lifting standard for their job (36) These data suggest that some Soldiers assigned to heavy or very heavy category jobs are likely to have difficulty performing the physically demanding tasks of their assigned MOS.

Surveys of Soldiers' subjective assessments of their job performance provide further insight into the potential for physical mismatches. In a 1994-95 study of 10 selected MOSs, Dr. Elizabeth Brady of USARIEM reported that 51% to 79% of Soldiers had no problems completing the physically demanding tasks of their MOS (Briefing to Secretary of the Army [MR&A], 15 August 1995). The reverse of this statistic is that 21%-49% of Soldiers reported experiencing strength-related job performance problems. A more recent survey was sponsored by the Department of Defense and conducted under the supervision of a tri-service committee (Physical Strength Working Group [PSWG]). Out of 36,000 mailings to first-term enlisted service members, 5990 men and 1121 women (20% response rate) responded to a mailed survey (9). 78% of those surveyed reported they had no strength-related problems, while 15% reported having had problems 1-3 times in the previous year. Twice as many women (26%) as men (13%) reported experiencing a lack of adequate strength to perform their jobs 1-3 times in the last year. 74% of Soldiers felt they had the aerobic endurance to perform their job. While the results reflected the upper range of Soldiers reported by Brady (the MOS with the fewest strength-related problems was Administrative Specialist (71L), where 79% reported no problems), the conclusions were very different. The report did not break out the data by service or MOS. In spite of the relatively high proportion of men and women who reported inadequate strength and endurance for the job the main conclusion was that neither a lack of strength nor a lack of cardiovascular endurance was a pervasive problem in the military.

As outlined above, lifting strength (35) and survey data (Brady, Briefing to Secretary of the Army [MR&A], 15 August 1995) suggest that physical mismatches occur and provide an estimate of the extent of the problem. If even a modest percentage of Soldiers are not physically capable of performing their jobs, missions may not be completed, Soldiers may be injured more frequently, and there may be an unequal distribution of labor, all of which can negatively affect combat readiness.

Soldiers who do not have adequate physical capability will not be able to complete specific tasks independently, or complete them in the time allotted. Fortunately, it appears that Soldiers eventually get the job done, as less than 1% of Soldiers surveyed by the PSWG reported they did not complete tasks if they lack adequate strength (9). More likely, the Soldiers asked another Soldier to work with them to complete the task (22%), or someone else completed it for them (6%). These solutions may result in manpower allocation problems, as two Soldiers are utilized to do a task programmed for one.

The three generally accepted methods used to avoid physical mismatches are ergonomic redesign, administrative controls, and pre-assignment screening. Ergonomic redesign of a task may be as simple as changing the vertical location for storing a frequently used item to reduce the need for bending or reaching. Redesign recommendations can be made by trained ergonomists following a thorough task analysis. Administrative controls would include use of specialized equipment or training programs. For example, a mechanical lifting aid might be required, or task-specific strength training programs may be needed.

Pre-assignment physical screening is typically the last resort to reduce injuries and prevent strength mismatches between workers and job demands. In 1985 USARIEM developed a pre-assignment screening program using the incremental lifting device, but the program was not made mandatory and was terminated in 1990 (2). The British Army has recently developed a system to test incoming recruits. Recruits are required to perform a number of physical performance tests that have been shown to be predictive of militarily relevant tasks such as lifting, carrying, and loaded road marching (30,31). The Dutch Army has a similar pre-assignment screening program in place that also includes a physical training program to physically prepare the Soldier for their assigned job (42-45) The US Army is experimenting with a physical testing program for new recruits called Assessment of Recruit Motivation and Strength (ARMS). Recruits not meeting the Army body fat standard (30% for men and 36% for women) would normally be denied admission. The ARMS program will allow them to obtain a waiver if they are physically fit, so they can enter the Army at a higher percentage body fat. To get a waiver, the Soldier must pass a 5 minute modified Harvard Step test and a minimum standard for a 1-minute push-up test. The effectiveness of this program to recruit and retain Soldiers has not yet been established (COL Christine Scott, personal communication, 21 September 21 2006).

When designing a pre-assignment physical abilities test, the physiological determinants of job performance must be identified. In a study of college students

performing two militarily relevant occupational tasks (repetitive lifting and backpacking), the variables that were most highly correlated with both tasks (range r=-0.54 to 0.60) were bench press strength, maximum box lift strength, squat endurance and 2-mile run time (23). Most of the aforementioned studies used generalized tasks that were similar to tasks performed by Soldiers in many different jobs (42-45). The cost and complexity of customizing a pre-employment physical screening test to each physically demanding MOS in the Army would be prohibitive. While Soldiers may be required to perform Army Readiness Testing and Evaluation Plans (ARTEPs), many of the field tasks are multi-person tasks and Soldiers are rated on team performance rather than individual Soldier performance. In addition, many of the tasks are not physically demanding. For this reason, there is very little information concerning the ability of the individual Soldier to perform the physically demanding tasks of their assigned MOS.

In order to accurately quantify the performance problems associated with a physically demanding MOS, we chose to focus on one MOS. The MOS selected, Light-Wheel Vehicle Mechanic (63B), has a "very heavy" category physical demand rating (11). Survey data showed that 25% of female and 9% of male Light-Wheel Vehicle Mechanics had strength-related problems performing their job (E. Brady, Briefing to Sec Army [MR&A], 15 Aug, 1995). 7% reported having difficulty on one occasion and 21% reported difficulty performing their job due to inadequate muscle strength on two to four occasions in the previous year (E. Brady, Briefing to Sec Army [MR&A], 15 Aug, 1995). A study of Utah National Guardsmen reported that mechanics had a high concentration of disability claims (28). Based on isometric strength testing of lifting in job-related positions, these authors estimated that 38% of mechanics were not physically capable of performing some of their job tasks (28). Inadequate strength is thought to result in higher injury rates. Data from 1990-94 indicate that women 63Bs have the highest rate of hospitalizations for musculoskeletal injuries of the 25 most densely populated MOS (4). Data from the Defense Medical Surveillance System (DMSS) indicated that among all Army MOS, injury rates for 63B were the fifth highest for men and second highest for women in 1999 (DMSS, Personal communication, COL Mark Rubertone, USACHPPM). For men, the MOS with the highest injury rate (11H, Heavy anti-armor infantryman) had a cumulative injury incidence only 7% higher than 63Bs. The MOS with highest injury rate for women (31C, Radio operator-maintainer) had only 145 women Army-wide. Male Light-Wheeled Vehicle Mechanics have the 8^{th} highest rate of occupational low back disability, while females have the 3^{rd} highest rate of all Army MOSs (7). In a retrospective study of 63Bs, the activities most associated with injury in order of incidence were physical training, mechanical work, sports, airborne-related activities, and road marching (19). Soldiers with a higher body mass index had a higher injury risk (19). The MOS 63B contains the seventh largest population of men (≈9,100) and tenth largest population of women (≈990) in the Army (M. Rubertone, USACHPPM, DMSS, personal communication, December 2000). The rank distribution is 36% E1-E3, 24% E4, and 40% E5-E7 (E. Zapanta, personal communication, PERSCOM, December 2000). A concentration on the MOS Light-Wheeled Vehicle Mechanic was expected to allow us to reach the primary goal of determining if physical mismatches are occurring.

The purposes of this study were 1) to determine the capability of a representative sample of Light-wheel Vehicle Mechanics (63B) to perform tasks specific to their military occupational specialty; and 2) to evaluate the relationship between Soldiers' muscular strength and body composition and performance on physically demanding 63B tasks.

METHODS

SOURCE OF VOLUNTEERS

Volunteers were recruited from the active duty population of 63B and 63 S (Heavy Wheel Vehicle Mechanics) Soldiers working in 63B positions at Ft. Bragg, NC. Subjects were men and women, E-7 (Sergeant First Class) or below, and between the ages of 18 and 40. The principal investigator, one of the associate investigators, or a qualified individual associated with the USARIEM/WAMC Medical Research Facility briefed volunteers. All procedures and risks were explained both orally and in writing prior to obtaining informed consent. If a volunteer agreed to participate, the volunteer and witness signed all official paperwork together. Females were screened for pregnancy, and all Soldiers were asked if they were currently on profile (or injured) prior to testing. Pregnant, profiled and injured Soldiers were excluded from the study.

STUDY DESIGN

Volunteers participated in one day of testing (approximately 4 hours), which included collection of descriptive data, muscle strength testing, body composition assessment, task simulations, and completion of questionnaires. Muscle strength, body composition and survey testing took place at Womack Army Medical Center (WAMC), Ft. Bragg, NC, in the USARIEM/WAMC Medical Research Facility. The 63B tasks were performed at a motor pool in the 1st Corps Support Command. Subjects were assigned to start testing on the physical fitness measurements (Laboratory) or on the task simulations (motor pool) in small groups. Soldiers remained at one testing location until all tests at that location were completed. They were then transported to the second testing location, where the other tests were completed The time at each location was typically 1-2 hours, for a total test time of 3-4 hours per volunteer.

JOB ANALYSIS BACKGROUND

A job analysis of the physically demanding tasks of a 63B was conducted by the Ergonomics Group of USACHPPM. Task analysis is a standard part of the mission of the Ergonomics Division and is typically done to reduce the risk of injury to Soldiers in an MOS. The process consisted of five phases:

Descriptive Phase The critical task documents for the MOS 63B were collected and reviewed, including task descriptions, maintenance guidance, training packages and lesson plans, performance standards and criteria, and any required abilities (cognitive, psychomotor, physical, sensory/perceptual, interactive/social, and knowledge/skills).

Expert Rating Phase. This phase involved focus group discussions conducted with 63B instructors and NCOs (n=10) from the 63B10 Light-Wheel Vehicle Mechanic Course, Ft. Jackson, SC, and junior and senior 63B enlisted Soldiers (n=37) from Ft. Bragg, NC. From a comprehensive list of 27 physically demanding MOS tasks, these ratings and discussions identified the top 20 physically demanding tasks for the 63B MOS. Tasks were further narrowed down to a consensus list of the top 10 most physically demanding tasks and problematic task elements, subtasks and tools. Table 1 lists the top 10 physically demanding tasks identified by the subject matter experts (SMEs).

Table 1. Top 10 most physically demanding tasks performed by 63B Soldiers.

Replace Radiator on a Light-Wheeled Vehicle
Replace Starter on a Light-Wheeled Vehicle
Correct Malfunction of Knuckle and Geared Hub on a Light-Wheeled Vehicle
Replace Half-shaft on a Light-Wheeled Vehicle
Replace Front and Rear Brake Pads on a Light-Wheeled Vehicle
Replace Universal Joints on a Light-Wheeled Vehicle
Replace Propeller Shaft
Correct Alternator Malfunction
Correct Malfunction of Batteries on a Light-Wheeled Vehicle
Maintain Assigned Toolkit

Soldier Survey Phase. The purpose of this phase was to validate the task list provided by the instructors at Ft. Jackson. It involved a written survey of a representative sample of 63B Soldiers (n=82) at Ft. Bragg, NC. Responses to this survey identified the top 10 physically demanding tasks and subtasks and provided information about the type of physical demand, the frequency and duration of the tasks, and rated physical exertion required to complete the tasks.

Task Analysis Phase. This phase involved detailed task analyses and video recording of the four physically demanding tasks. The task analyses and expert evaluations resulted in the dentification of specific physically demanding, frequently occurring subtasks

Task Simulation Phase. This phase involved the development of procedures to test performance on the four most physically demanding subtasks. The sub-tasks selected were replacing the starter, replacing the alternator, changing a tire, and changing the battery. All tasks were performed on a High-Mobility, Multi-Purpose, Wheeled-Vehicle (HMMWV). One of the sub-tasks selected, changing a tire, was not specifically listed in the top 10 tasks. However, removing/replacing a tire was the most physically demanding sub-task for seven of the top 20 physically demanding tasks (correct malfunctioning knuckle/gear hub, replace front and rear brake pads, replace master cylinder, replace brake shoes, replace brake calipers, replace brake rotors, and replace hand brake shoes). For this reason, and because it is done frequently by nearly all 63Bs, it was selected for testing.

EXPERIMENTAL PROCEDURES

Descriptive Measurements Subjects were asked their age (yr), birth date, and unit assignment. Height (cm) was measured using a stadiometer (Model GPM, Seritex, Inc, Carlstadt, NJ). Body weight (kg) was measured using a digital scale.

Body composition was measured using dual-energy X-ray absorptiometry (DEXA, Hollogic, Bedford, MA). The Soldier lay face up and laterally centered on the scanning table. Velcro straps were used to keep the knees together and support the feet tilted at a 45°-angle from the vertical. Scanning was in 1 cm slices from head to toe using the 6-minute scanning speed. Quantitative Digital Radiography (QDR) for Windows software provided an estimate of percent body fat, fat mass, bone mass, bone mineral density, fat-free mass, and lean mass (fat-free mass minus bone mass).

Task Performance Volunteers completed four physically demanding tasks typically performed by 63Bs. Each task was demonstrated and explained, and the volunteer was given an opportunity to become familiar with the apparatus. There was no specific order of testing. The alternator, starter and tire change tasks were performed on a HMMWV. The battery change was executed on a simulator, which duplicated the workstation and object dimensions. Actual components of the HMMWV were incorporated into the battery change mock-up station to increase the fidelity and simulation realism. For all tasks, the most physically demanding sub-tasks were included in the procedure, rather than the most technically challenging aspects.

Prior to performing each task, each subject was shown a videotape describing the tasks to be performed and was given an opportunity to ask questions. Volunteers were also asked to respond to three questions concerning the frequency of task performance, the date of most recent task performance and how well they thought they would perform the task. At the completion of the lifting and lowering portions of each task, Soldiers were asked for a rating of perceived exertion (10) to indicate their perception of the physical demands of that portion of the task. They were also asked to rate their skill and performance on the task (Appendix A).

Removing and Installing an Alternator. This task involved reaching into the engine compartment and holding and positioning an alternator with one hand while positioning the bolts, washers, and nuts that hold the alternator in place with the other hand The alternator is located 45" from the ground, and 16" into the engine compartment. The unmodified AMA-5102UT (60-amp) alternator used in these trials weighed 35 lbs.

The Soldier was instructed to remove and install the alternator, to work at a typical pace and to complete the task to the point of tightening the fan belts. The time to remove and replace the alternator was recorded. The Soldier was given the opportunity to rest between installation and replacement, and before continuing with the next task simulation. The rest times were also recorded.

Removing and Replacing Batteries. While working in a standing, forward-leaning position at the side of the simulation station, the Soldier had to remove the bolts of the metal battery guard, and pull it off. The cables were removed. One at a time, the Soldier lifted each of two batteries out of the simulator and lowered them to a marked area on the floor The Soldier then replaced each battery into the battery compartment and secured the cables and guard. The task required a forward reach of 15". The batteries were located 35" from the ground The unmodified batteries weighed 74 lbs each. The Soldier was instructed to remove and replace the battery, working at a typical pace and completing the task to the performance standard specifications. The time to remove and replace the batteries was recorded. The Soldier was given the opportunity to rest between installation and replacement, and before continuing with the next task simulation.

Removing and Installing a Starter Motor. This sub-task involved working under the vehicle in a supine position on a creeper with the arms extended upward. The task required a forward/overhead reach of 23" from the ground. The starter motor weighed 55 lbs. The Soldier was instructed to remove the starter motor, place it on the ground beside the vehicle, then install it, working at a typical pace until the starter was bolted onto the engine. The starter was held and positioned with one hand while fastening the bolts, washers, and nuts that hold it in place with the other hand. The times to remove and replace the starter were recorded The Soldier was given the opportunity to rest between installation and replacement, and before continuing with the next task simulation.

Removing and Replacing a Tire. The vehicle was raised such that the tire was 2" off the ground, with tire chucks inserted to prevent tire rotation. The Soldier loosened and removed the eight lug nuts, pulled the wheel off the wheel assembly, removed the tire chucks and laid the wheel down in the marked area next to the vehicle. To replace the tire, it was lifted from its side-lying position, rolled next to the hub, lifted 2", positioned back onto the wheel assembly, the tire chucks were replaced, and the lug nuts fastened. The tire weighed 120 lbs. The Soldiers were instructed to remove and replace the tire, working at a typical pace. The time to remove and replace the tire was recorded. The Soldier was given the opportunity to rest between installation and replacement, and before continuing with the next task simulation.

Muscular Strength

Two tests of dynamic strength (bench press and incremental dynamic lift) and seven tests of isometric strength (handgrip, back extension, shoulder flexion, elbow flexion, elbow extension, leg flexion, and leg extension) were made.

The bench press was performed while lying supine on a flat bench (Olympic) beneath a standard Olympic weight bar Keeping the feet flat on the floor the volunteer lowered a weight bar from a straight arm position, down to the chest and returned to a straight arm position without bouncing the load off the chest. Proper lifting procedures were described and demonstrated. Volunteers were given a chance to perform the movement in an unloaded condition. A warm-up of 5-10 repetitions at 40%-60%

estimated maximum was followed by a 3-5 minute rest. Then, three repetitions at 60%-80% maximum were completed, again followed by 3-5 minutes rest. Approximately three to five subsequent lifts were made to determine the 1RM, with loads increased by 5%-10% each attempt. Additional lifts were completed as necessary. 3-5 minutes rest was provided between each near-maximal lift attempt. A successful lift was one that completed a full range of motion without deviation from proper form. Two spotters were present to assist and coach each lift (33).

Lifting strength was measured using the incremental dynamic lifting device (IDL) previously used in many studies conducted by the Military Performance Division (16,41,46). The test simulated lifting a box with handles from ground level onto a 2-1/2 ton truck. Volunteers lifted handles attached to the carriage of a weight stack machine vertically from 20 cm to 152 cm. The carriage moved vertically between two guide rails. The Soldier began by grasping the handles of the weight carriage and assuming a bent-knee, straight back position with the head up and feet shoulder width apart. The load was accelerated upward by straightening the legs and pulling up on the handles of the load carriage, which were held in an overhand grip. The wrists were simultaneously rotated under the handles, and the load was pressed to the 152 cm mark on the vertical guides. The initial load was 18.2 kg and was increased in 9 kg increments for men and 4.5 kg increments for women until the Soldier began to experience difficulty. At this time the increments were reduced by half (4.5 kg for men and 2.3 kg for women) until the Soldier was unable or unwilling to complete the lift using a safe technique. Soldiers were provided detailed instruction on lifting technique, adequate practice trials, and inter-trial rest periods of a minimum of one minute at near maximum loads (25,40).

Isometric handgrip strength was measured using a device and procedures described previously (29,41). The grip device contains a tension-compression transducer (BLH Electronics, model C2M1, Waltham, MA) attached to a digital-peak-tension readout (BLH Electronics transducer indicator, model 450A, Waltham, MA). The test was conducted in a seated position with the forearm resting on a padded table surface. The handgrip apparatus was adjusted to an angle of 150° at the metacarpalphalangeal joint and 110° at the proximal interphalangeal joint of the third finger. Handgrip strength of the self-determined dominate hand was measured. While keeping the forearm on the pad, the volunteer increased to maximum grip strength over a period of 1-2 sec. Lifting the forearm off the pad, or jerking movements resulted in a re-trial.

Isometric back extension strength was measured using the Triple Strength Device (17). The Soldier stood facing the device, with their hips against the padded support. A padded strap was cinched around the shoulders one inch below the acromium process. On command, the Soldier extended his/her back against the strap restraint, while keeping contact with the hip plate. The Soldier maintained maximum pressure for 3-4 sec, with no jerking movement permitted. The back extension device contains a tension-compression transducer (BLH Electronics, model C2M1, Waltham, MA) attached to a digital-peak-tension readout (BLH Electronics transducer indicator, model 450A, Waltham, MA). Peak force was recorded.

Isometric elbow flexion and extension was measured while lying supine with the elbow-testing angle at 90° for both tests. The arm was attached to a load cell using a padded wrist cuff with an adjustable cable running parallel to the body. The Soldier was secured to a padded table with belts to prevent movement during maximal contraction. The Quantitative Muscle Assessment System (QMA, Gainesville, GA) for measuring isometric strength consists of an adjustable, padded examining table, an orthopedic frame, and force transducers. On command the Soldier contracted the forearm flexors or extensors, building to maximum over a 1-2 sec period and maintaining that force for an additional 2-4 sec. The computerized system recorded the force produced from each contraction into a database (QMA).

Isometric shoulder flexion strength was measured while lying supine on the padded table of the QMA, with the arms extended straight up, perpendicular to the body and the floor. A shoulder width handle was grasped with the hands, palm inward. On command, the volunteer pulled upward (toward the head) on the handle building to maximum strength over a 1-2 sec period and maintaining the force for an additional 2-4 sec. The handle was attached by adjustable cable to a force transducer (SM 1000) mounted on a traction frame. The computerized system recorded the force produced from each contraction into a database (QMA).

Isometric leg flexion and extension strength was measured using a Biodex Isokinetic Measurement System. The subject was seated, with the hips and legs secured with Velcro straps. The dynamometer head was aligned with the geometric center of the lateral femoral condyle. A padded cuff on the lower portion of the lever arm was attached at the ankle with Velcro straps. The knee angle was 90°. The subject pushed forward against the cuff as if to extend the leg for three maximum isometric trials, and then pushed backward against the cuff as if to flex the leg for three maximum effort isometric trials.

The testing procedures for all isometric tests were identical The volunteer was properly positioned and secured at all of the testing stations. Three maximum effort trials were performed, with a minimum of 1 min rest between trials. The highest two trials within 10% of one another were averaged for the final score in kg. Additional trials were performed as necessary, up to a maximum of five trials, to obtain two trials within 10%.

Army Physical Fitness Test (APFT)

The APFT consisted of 3 events, push-ups, sit-ups, and a 2-mile run(10). For push-ups, the Soldier was required to lower his body in a generally straight line to a point where his upper arm was parallel to the ground, then return to the starting point with elbows fully extended. For sit-ups, the Soldier bent his knees at a 90° angle, interlocked his fingers behind the head, and a second person held the Soldier's ankles to keep the Soldier's heels firmly on the ground. The Soldier raised his upper body to a vertical position so that the base of the neck was anterior to the base of the spine and then returned to the starting position. The number of push-ups and sit-ups successfully completed in separate 2 minutes periods were recorded. Run performance was

measured as the time to complete the 2-mile distance. The Soldier's unit was contacted by telephone and asked for the most recent APFT values.

Questionnaires

Physical Demands Self-Evaluation Questionnaire. Soldiers completed a questionnaire pertaining to their perception of the physical demands of MOS 63B (Appendix B). This survey is an abbreviated version of that developed by Cooper and Arabian for the Physical Strength Working Group (8). This survey was used to further validate the earlier survey results from the task analysis, to determine if Soldiers who report difficulty performing their job tasks are more likely to perform poorly on the simulated job tasks, become injured, or have reduced muscle strength.

Physical Activity Questionnaire. All volunteers completed a questionnaire concerning their customary level of physical activity (Appendix C). This information was used to determine the relationship between reported physical activity and likelihood of injury, muscle strength, and performance of the simulated job tasks. This questionnaire was developed by USACHPPM personnel and has been used in numerous injury epidemiological investigations (12,14,15).

RESULTS

PHYSICAL CHARACTERISTICS

All volunteers were active-duty 63Bs and 63Ss working in a 63B position and stationed at Ft. Bragg, NC Table 2 lists the physical characteristics of the volunteers. As expected, men were taller and heavier than women, but there was little difference in age, BMI or time in MOS.

Table 2. Subject characteristics (Mean ± SD).

	Men (n=135)	Women (n=9)	All (n=144)	F/M Ratio (n=144)
Age (yrs)	25.5±6.0	25.4±4.3	25.5±5.9	99.6
Height (cm)	176.1±6.6[1]	161 5±6.2	175.2±7.5	91.7
Weight (kg)	80.8±13.1[1]	67.5±11.4	80.0±13.4	83.5
BMI (kg/m^2)	26.1 ± 3.8	25.7 ± 3.0	26.0 ± 3.8	98.5
Time in MOS (yrs)	3.2±1.3	3.5±1.3	3.3±1.3	109.4

[1] Men significantly different from women ($p<0.01$).

The rank distribution of the volunteers is listed in Table 3. The majority of volunteers (42%) were Specialists/Corporals (E4). 35% of the volunteers held the rank of SGT or above, while only 23% were lower enlisted. This is in consonance with the reports for average time in MOS of 3 years or more. 74% of the volunteers had served more than two years in a 63B position and were experienced mechanics.

Table 3. Frequency distribution of rank.

Rank	Count	Cumulative Cases	Proportion of Sample (%)	Cumulative Proportion (%)
E1	1	1	0.7	0.7
E2	14	15	9.7	10.4
E3	19	34	13.2	23.6
E4	61	95	42.4	66.0
E5	26	121	18.1	84.0
E6	14	135	9.7	93.8
E7	9	144	6.3	100.0

The results of the DXA analysis of body composition are listed in Table 4. As expected, men had greater BMC, more lean mass, less body fat and a lower percentage body fat than women.

Table 4. DXA estimate of body composition (Mean ± SD).

	Men n=135	Women n=9	All N=144	Female/ Male Ratio
BMC (g)	2918.1±452.5[1]	2255.4±327.4	2876.6±473.1	77.3
BMD (g/cm^2)	1.2±0.1	1.1±0.1	1.2±0.1	91.7
Fat Mass (kg)	15.9±6.7[1]	21.7±7.1	16.2±6.9	136.5
Lean Mass (kg)	60.4±7.7[1]	42.4±5.0	59.2±8.7	70.2
Lean Mass + BMC(kg)	63.3±8.0[1]	44.6±5.3	62.1±9.1	70.5
% Body Fat	19.4±6.1[1]	32.0±5.7	20.2±6.8	164.9

[1] Men significantly different from women ($p<0.01$)

MUSCLE STRENGTH

The results of the muscle strength testing are listed in Table 5 by sex. Women's strength compared to men's ranges from 52% to 67%.

Table 5. Muscle Strength (kg) by sex (Mean ± SD) and the male:female ratio.

	Men n=135	Women n=9	All n=144	Male/Female Ratio
Bench Press	85.2±19 4 [1, a]	44.4±7.5	82.6±21.3 [c]	52.1
IDL	71.3±12.7 [1, a]	38.8±5.1	69.3±14.7 [c]	54.4
Hand Grip	52.7±8.5[1]	33.3±7.6	51.5 ± 9.6	63.1
Back Extension	83.1±14.7[1]	52 1±8.0	81.1±16.2	62.6
Right Elbow Extension	27.6±8.0[1]	16.1±3.6	26.8±8.2	58.3
Left Elbow Extension	26 5±6.8[1]	15.6±3.8	25.8±7.2	58.8
Right Elbow Flexion	29.7±6.4[1]	19.6±4.3	29.1±6 7	65.9
Left Elbow Flexion	29.9±6.3[1]	20.1±3.6	29.3±6 6	67.2
Shoulder Flexion	30.1±6.3[1, b]	18.5±4.4	29.4±6.8[d]	61.4
Right Leg Extension	25.5±6.3[1, a]	15.6±4.3	24.9±6.7 [c]	61.1
Left Leg Extension	24.7±5.7[1, a]	15.4±4.5	24.1±6.1 [c]	62.3
Right Leg Flexion	10.3±2.8[1, a]	6.8±1.8	10.3±2.9 [c]	66.0
Left Leg Flexion	10.3±2.4[1, a]	6.8±1.8	10.1±2.5 [c]	66.0

[1] Men significantly different from women ($p<0.01$).
[a]n=133, [b]n=134, [c]n=142, [d]n=143.

MECHANICAL TASK PERFORMANCE

The times recorded during performance of the mechanical tasks are listed in Table 6. The distribution of total time without rest for each task can be found in Table 7. Thirteen Soldiers could not complete the SR task, and two elected not to attempt it due to previous injuries. All other tasks were successfully completed by all Soldiers. The removal time was similar for all four tasks. The Alternator and Starter tasks had the longest install times.

Table 6. Time (min) recorded during performance of the four mechanics tasks (mean ± SD)

	Alternator Replacement n=144	Battery Change n=144	Starter Replacement N=129	Tire Change n=144
Removal time	3.8±1.5	3.8±1.5	3.1±2.1	3 2±0.8
Rest time	4.8±2.0	3.5±1.5	4.6±2.5	3.6±0.8
Install time	12 0±6.3	7.6±2.6	13.8±7.2	8.1±2.1
Total time without rest	15.8±7.3	10.7±3.8	16.4±8.9	11.2±2.8

Table 7. Percentile distribution of total time without rest (sec) during the four tasks

	Alternator Replacement	Battery Change	Starter Replacement	Tire Change
Percentile	N=144	N=144	N=129	N=144
10	524 5	411.0	457.0	512 5
20	606.0	461.0	555.0	545 0
30	682.0	503.0	606.5	578.5
40	767 0	540.0	705.0	611 0
50	853.0	583.0	830.0	644.5
60	983.0	643.0	1000.0	680.0
70	1071.5	708.0	1228.0	726.0
80	1211.0	811.0	1476.0	792.0
90	1445.0	1007.0	1704.0	860.5
100	3987.0	1387.0	2586.0	1455.0

The Ratings of Perceived Exertion (RPE) recorded during performance of the four mechanics tasks are in Table 8. Lowering the alternator (35 lbs) and Tire (120 lbs) was perceived as less stressful than the batteries (75 lbs each) and starter (55 lbs)

Table 8. RPE recorded during performance of the four mechanics tasks

	Alternator Replacement n=144	Battery Change n=144	Starter Replacement n=129	Tire Change n=144
Lower/Remove RPE	9.3±2.3	11.0±2.2	11.6±2.5	9.4±2.2
Lift/Raise RPE	9.6±2.3	11.4±2.2	13.2±2.4	9.9±2.3
Position RPE	10 0±2.7	NA	15.2±2.8	9.7±2.6
Overall RPE	10.0±2.1	10.7±2 3	13.9±2.5	10.3±2.2

NA=not applicable.

Tables 9-12 list the task times and RPEs by sex. Women took significantly longer to remove and replace both the tire and the batteries than the men. The rest times for these two tasks were longer for women as well. Examination of the task RPEs revealed that the women found several portions of tasks to be more difficult than the men. Lowering the alternator was perceived as more difficult by women, as were all aspects of the battery change and starter replacement tasks. The gender difference in RPE for lifting the tire did not reach the level of statistical significance (1.2 unit difference in RPE, p=.13), nor did the overall RPE for starter replacement (2.3 unit difference in RPE, p=.11). However, both results may be considered of practical import.

Table_9. Alternator replacement task performance variables by sex (mean ±SD)

Alternator	Men n=135	Women n=9	All n=144
Removal Time	3.8±1.6	3.7±1.2	3.8±1.5
Lower RPE	9.2±2.3[1]	10 8±1.3	9.3±2.3
Rest Time	4.8±2.0	4.8±1.4	4.8±2.0
Install Time	11.9±6.4	11.7±4.3	12.0±6.3
Lift RPE	9.6±2.4	9.9±1.9	9.6±2.3
Position RPE	10.0±2 7	10.4±2.5	10.0±2.7
Total Time Excluding Rest	15.8±7.4	15.5±5.4	15.8±7.3
Overall RPE	9.9±2.1	10.4±1.6	10.0±2.1

[1]Men significantly different from women (p<0.05).

Table_10. Battery change task performance variables by sex (mean ±SD).

Battery	Men n=135	Women n=9	All n=144
Removal Time (min)	3.0±1.3[1]	4 3±1.8	3.1±1.3
Lift out RPE	10.9±2 2[1]	13.0±1.4	11.0±2.2
Rest Time (min)	3.4±1.4[1]	4.6±2.7	3.5±1.5
Install Time (min)	7.5±2.5	9.0±3.7	7.6±2.6
Lift in RPE	11.2±2.2[1]	14.1±1.5	11.4±2.2
Total Time excluding Rest (min)	10.6±3.6[1]	13.2±5.3	10.7±3.8
Overall RPE	10.6±2.2[1]	11.8±3.4	10.7±2.3

[1]Men significantly different from women (p<0.05).

Table 11. Starter replacement task performance variables by sex (mean ±SD).

Starter	Men n=123	Women n=6	All n=129
Removal Time (min)	3.0±2.1	3.1±1.2	3.1±2.1
Lower RPE	11.4±2.4[1]	14.0±2.0	11.6±2 5
Rest Time(min)	4.4±2.4	4.6±1.6	4.6±2.5
Install Time (min)	13.2±6.8	14.3±6.0	13.8±7.2
Raise RPE	13.1±2.4 [1]	14.0±1.7	13.2±2.4
Hold RPE	15.0±2.8[1]	16.8±2.0	15.2±2.8
Total Time Excluding Rest (min)	20.7±10.1	21.9±8.2	16.4±8.9
Overall RPE	13.7±2.4[1]	16.0±2.3	13.9±2.5

[1]Men significantly different from women (p<0.05).

Table 12. Tire change task performance variables by sex (mean ±SD).

	Men n=135	Women n=9	All n=144
Removal Time (min)	3.1±0.7[1]	4.0±1.2	3.2±0.8
Remove Tire RPE	9.4±2.6	9.1±2.3	9.4±2.2
Rest Time (min)	3.6±0 7[1]	4 7±1.3	3.6±0 8
Install Time (min)	8.0±2 0[1]	10 0±3.0	8.1±2.1
Lift RPE	9 8±2.9	11.0±1.7	9.9±2.3
Place Tire RPE	10.1±2.7	10.8±2.3	10.1±2.7
Position RPE	9.7±2.7	9.8±2.6	9.7±2.6
Total Time excluding Rest (min)	11.1±2.6[1]	14.1±4 2	11.2±2.8
Overall RPE	10.3±2.2	10.8±1.5	10 3±2.2

[1]Men significantly different from women ($p<0.05$).

The above data on starter replacement task performance only included subjects who successfully completed the task. A t-test was run to identify differences in the physical characteristics and muscle strength of the Soldiers who completed vs. those who did not complete the starter task. There were no significant differences in the physical characteristics or muscle strength between those who succeeded and those who failed to complete the starter replacement task (Table 13). The sample sizes were small, particularly for women, making it difficult to find differences between the groups (complete vs. incomplete). The actual differences in the descriptive measurements were generally small.

Table 13. Comparison of successful vs. non-successful completion of starter task by sex.

	Male Complete (n=123)	Male Incomplete (n=10)	Female Complete (n=6)	Female Incomplete (n=3)
Variable	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Age	25.4 ± 6.1	26.6 ± 5.3	24.8 ± 2.1	26.7 ± 7.6
Rank	4.2 ± 1.3	4.2 ± 1.2	4.5 ± 0.8	4.3 ± 2.1
Height (cm)	175.8 ± 6.6	178.3 ± 6.0	161.8 ± 7.1	160.8 ± 5.3
Weight (kg)	80 8 ± 13.2	81.2 ± 13.2	66.5 ± 10.0	69.4 ± 16.1
BMI	26.1 ± 3.9	25.5 ± 3.5	25.3 ± 2.4	26.6 ± 4.6
FFM (kg)	63.1 ± 8.1	64.2 ± 8.3	43.8 ± 4.3	46.2 ± 7.7
% Body Fat	19.6 ± 6.0	18.6 ± 7.4	32.4 ± 5.2	31.3 ± 7.7
Bench Press 1RM (kg)	85.6 ± 19.6	83.0 ± 19.8	45.5 ± 8.1	42.4 ± 7.3
IDL 1RM (kg)	71.6 ± 12.8	67.7 ± 11.4	38.6 ± 5.6	39.4 ± 5.2
Hand Grip (kg)	52.5 ± 8.4	53.8 ± 8.8	32.8 ± 7.0	34.4 ± 10.4
Back Ext. (kg)	83.5 ± 14.9	79.8 ± 14.8	50.3 ± 6.8	56.1 ± 10.3
Elbow Ext. R (kg)	27.4 ± 7.6	29.6 ± 11.8	16.6 ± 4.2	15.0 ± 2.3
Elbow Ext. L (kg)	26.5 ± 6.9	26.8 ± 7.0	16.0 ± 4.5	14 7 ± 2.3
Elbow Flex. R (kg)	29.7 ± 6.5	28.9 ± 4.5	18.3 ± 2.8	22.4 ± 6.2
Elbow Flex. L (kg)	29.9 ± 6.3	29.0 ± 5.4	19.2 ± 2.6	21.9 ± 5.2
Shoulder Flexion (kg)	30.3 ± 6.3	27.2 ± 4.6	18.2 ± 3.0	19.1 ± 7.4
Leg Ext. R (kg)	248.4 ± 61.2	248.7 ± 57.1	142.9 ± 25.6	172.1 ± 68.5
Leg Ext. L (kg)	242.1 ± 53 5	236.3 ± 65.0	139.2 ± 36.5	173.9 ± 58.3
Leg Flex. R (kg)	101.7 ± 22 6	105.5 ± 23.9	64.6 ± 17.4	71.4 ± 22.2
Leg Flex. L (kg)	100.6 ± 23.3	100.0 ± 28.9	62.0 ± 17.3	77.3 ± 17.0

No statistically significant differences within sex.

Subjective Assessment of Mechanics Task Performance

The frequency count and percentages of responses to the question "Typical frequency of task performance" are shown in Table 14. The tire and battery tasks were performed daily by more than 10% of the volunteers, and nearly 50% performed both tasks at least 1-2 times per week. The alternator and starter replacement tasks were not performed as frequently. Sixteen percent of the mechanics replaced an alternator 1-2 times per week or more often, and only 12% replaced the starter that frequently. More than 80% of the mechanics replaced the alternator and starter 2-3 times per month or less frequently.

Table 14. Frequency count and percentage of responses to "Typical frequency of task performance."

	Alternator		Battery		Starter		Tire	
	Count	%	Count	%	Count	%	Count	%
daily	0	0.0	16	11.1	0	0 0	18	12 5
3-4 x/week	5	3.5	18	12 5	2	1 4	21	14.6
1-2 x/week	18	12 5	40	27.8	15	10 4	30	20 8
2-3 x/month	45	31 3	23	16 0	29	20 1	30	20 8
monthly	29	20 1	26	18 1	34	23.6	15	10 4
<monthly	47	32.6	21	14 6	62	43.1	30	20.8

The responses to the question "When was the last time you performed this task?" tended to support the frequency of task performance in the previous question (Table 15). 42% of the mechanics had performed the starter task within the past month, while 74% had changed vehicle batteries. The majority of mechanics had performed all the tasks within the previous 6 months. While only one mechanic had never done an HWMMV battery change, and three had never changed an HWMMV tire, seven reported having never changed an alternator, and nine reported never having changed a starter on an HWMMV.

Table 15. Frequency count and percentage of responses to "When was the last time you performed this task?"

	Alternator		Battery		Starter		Tire	
	Count	%	Count	%	Count	%	Count	%
w/in past week	22	15 3	71	49 3	20	13 9	59	41.0
w/in past month	51	35 4	35	24.3	41	28 5	37	25.7
w/in past 6 months	49	34 0	25	17.4	49	34.0	31	21 5
w/in past year	12	8 3	9	6 3	16	11 1	11	7 6
never	7	4 9	1	0 7	9	6 3	3	2 1
other	3	2 1	3	2 1	7	4 9	3	2 1

Mechanics were asked how well they thought they would perform each task before performing it (Table 16), and then to rate how well they performed it upon completion (Table 17). Most of the Soldiers (>70%) rated their performance as good to excellent prior to performing the alternator, battery, or tire tasks. Soldiers had less confidence in their skill at the starter task, as compared to the other tasks (53% rated their performance as good to excellent), and this may reflect the infrequency with which this task is performed. There were no significant differences in their ratings pre- to post-task performance, indicating the Soldiers had adequate experience to assess their skill, and that task performance did not change their self-rating.

Table 16. Frequency count and percentage of responses to "Rate how well you think you will perform on this (alternator replacement, battery change, etc.) task."

	Alternator		Battery		Starter		Tire	
	Count	%	Count	%	Count	%	Count	%
excellent	33	22.9	47	32.6	16	11.1	35	24.3
good	68	47.2	66	45.8	61	42.3	81	56.3
average	36	25.0	29	20.1	47	32.6	26	18.1
fair	7	4.9	1	0.7	13	9.0	2	1.4
poor	0	0.0	1	0.6	5	3.5	0	0.0
Missing	0	0.0	0	0.0	2	1.4	0	0.0

Table 17. Frequency count and percentage of responses to "Rate how well you did perform on this (alternator replacement, battery change, etc.) task."

	Alternator		Battery		Starter		Tire	
	Count	%	Count	%	Count	%	Count	%
excellent	28	19.4	42	29.2	17	11.8	32	22.2
good	76	52.8	66	45.8	61	42.4	83	57.6
average	32	22.2	34	23.6	31	21.5	28	19.4
fair	5	3.5	2	1.4	19	13.2	1	0.7
poor	3	2.1	0	0.0	9	6.3	0	0.0
missing	0	0.0	0	0.0	7	4.9	0	0.0

Soldiers were asked to rate their skill level compared to others within their company following completion of each task (Table 18). With the exception of the starter task (49%), at least 70% of Soldiers rated themselves as "very good" when compared to their peers. While this represents a high level of self-confidence for the alternator, battery, and tire change tasks, the starter task was the least familiar task for most Soldiers, and the self-ratings were lower. The task frequency and self-ratings data are presented graphically in Appendices D-G for each task.

Table 18. Frequency count and percentage of responses to "Compared to others within your company, how well would you rate your skill at this task?"

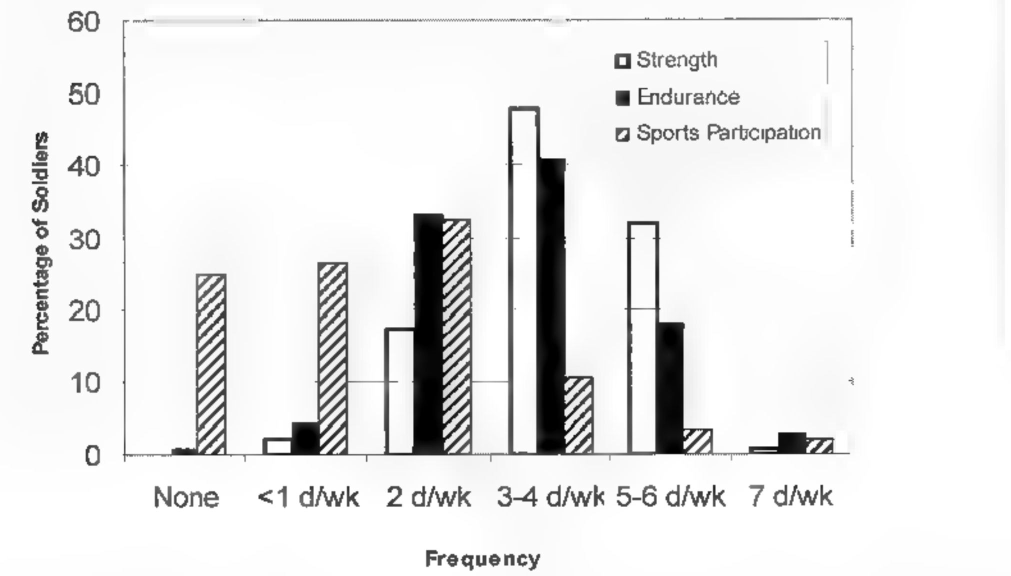
	Alternator		Battery		Starter		Tire	
	Count	%	Count	%	Count	%	Count	%
expert	37	25.7	42	29.2	25	17.4	36	25.0
very good	63	43.8	60	41.7	46	31.9	70	48.6
average	38	26.4	36	25.0	39	27.1	32	22.2
moderate	6	4.2	3	2.1	21	14.6	5	3.5
in training	0	0.0	2	1.4	6	4.2	1	0.7
novice	0	0.0	1	0.7	0	0.0	0	0.0
missing	0	0.0	0	0.0	7	4.7	0	0.0

PHYSICAL ACTIVITY QUESTIONNAIRE

Responses to the Physical Activity questionnaire indicate 63B Soldiers were participating in physical training at a high frequency. Eighty-one percent of Soldiers reported performing aerobic exercise 3-4 days per week or more, and 62% reported performing strength training exercise 3-4 days per week or more (Figure 1). In contrast,

only 16% reported participating in sports activities 3-4 days per week or more. Fewer than 50% reported participating in sports activities 1 day/week or more.

Figure 1. Frequency distribution (percentage) of responses to the question "How many days per week did you exercise to improve your strength (weight lifting) or endurance (aerobic exercise) or participate in sports activities in the last year?"



When asked how long they exercised during these sessions, 80% reported performing aerobic exercise for 31 min or longer each exercise session, while 72% reported performing strength training exercise for 31 min or longer during each exercise session (Table 19). On average, the 63Bs reported exercising for more than 3 hours per week. The time of activity for those who did participate in sports activities was equally divided among the 31-45 min, 46-60 min, and >60 min categories. Sixty-five percent of 63B Soldiers reported themselves as somewhat or much more active than others of the same age and sex.

Table 19. On days you performed Aerobic/Strength Training Exercise or Sports in the last year, how long did you exercise on average?

	Aerobic Exercise		Strength Training Exercise		Sports	
	Cases	Percentage of Sample	Cases	Percentage of Sample	Cases	Percentage of Sample
None	0	0 0	2	1 4	37	25.7
<15 min	0	0 0	3	2 1	3	2 1
16-30 min	29	20.1	36	25.0	11	7.6
31-45 min	52	36 1	44	30 6	30	20 8
46-60 min	53	36.8	49	34.0	21	21.5
>60 min	10	6 9	10	6.9	32	22 2

SELF-EVALUATION OF MOS 63B PHYSICAL DEMANDS QUESTIONNAIRE

The mechanics responded to a series of questions regarding the physical challenges of their MOS. Graphs of the distributions for each question can be found in Appendix H. Thirty-eight percent of 63Bs reported being unable to perform the full range of their duties at least one time within the past 12 months, due to a work-related, over-exertion injury (Table 20), but only 21% reported this injury had any effect on their productivity (Table 21).

Table 20. Responses to "During the past 12 months, how often have you been unable to perform the full range of your duties because of a work-related over-exertion injury?"

During the past 12 months, how often have you been unable to perform the full range of your duties because of a work-related over-exertion injury?				
	Count	Cumulative	Percent	Cumulative
never	89	89	61.8	61.8
1 or 2 times	40	129	27.8	89.6
3 or 4 times	14	143	9.7	99.36
5 or 6 times	1	144	0.7	100.0

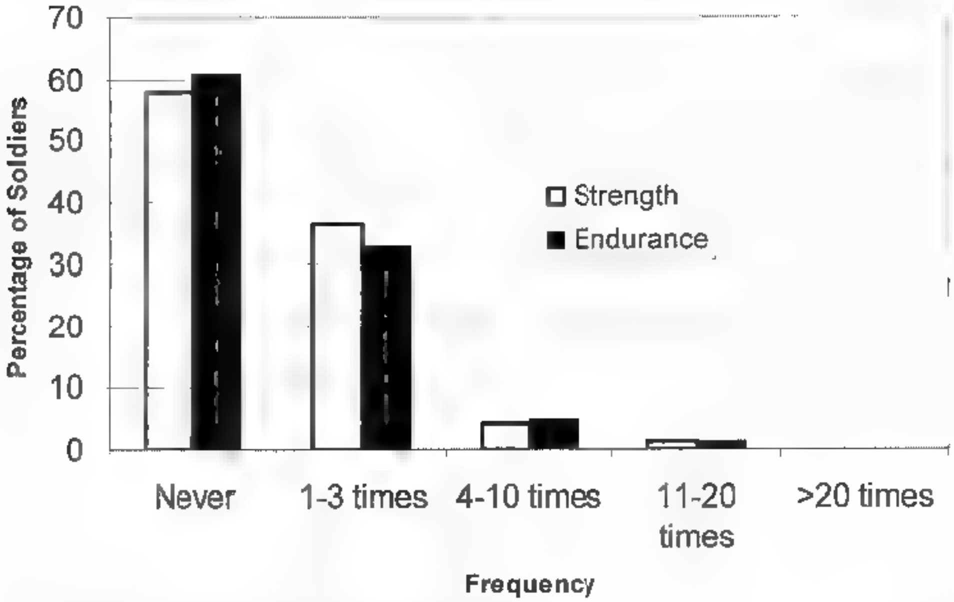
Soldiers were asked "During the past 12 months, how much additional work were you or your co-workers expected to perform because another co-worker experienced an over-exertion injury?" Twenty-one percent reported having to do additional work of <8 hours, and 25% reported having to do between 8 and more than 40 hours additional work (Table 21). It appears that either their perception of the impact of their own injuries was underestimated (only 21% reported having any impact on productivity), or the impact of their co-workers injuries was overestimated (47% reported having to do extra work for injured co-workers). A third possibility is that only the more capable 63Bs volunteered to participate in this study.

Table 21. Responses to questions related to the effect of over-exertion injuries on job performance and additional work.

During the past 12 months, how have over-exertion injuries affected your ability to perform your job?			During the past 12 months, how much additional work were you or your co-workers expected to perform because another co-worker experienced an over-exertion injury?		
	Count	Percent of Sample		Count	Percent of Sample
no impact	71	49.3	no injuries	43	29.9
did not impact job performance	43	29.9	no additional work in spite of injuries	34	23.6
<8 hrs reduced productivity	20	13.9	<8 hrs additional work	31	21.5
>8 hrs reduced job productivity	10	6.9	8-16 hrs additional work	20	13.9
			17-40 hrs additional work	13	9.8
			>40 hrs additional work	3	2.1

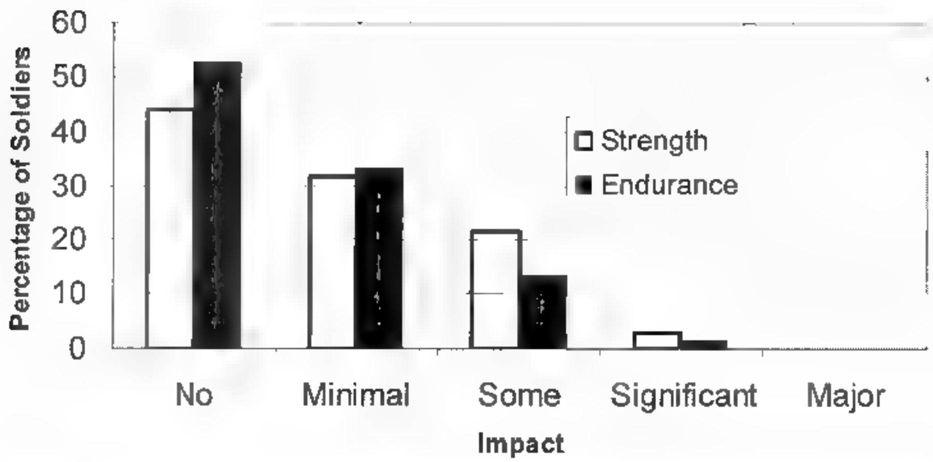
When asked (in separate questions) how often, over the last 12 months, they lacked either the physical strength or endurance to complete a physically demanding task, 58% reported they never lacked strength, and 60% reported they never lacked endurance. These data are illustrated in Figure 2. Although the majority of 63Bs had no problems, it should be noted that 42% had one or more instances when they lacked strength, and 40% had one or more instances when they lacked the endurance needed to complete a task.

Figure 2. Frequency distribution of answers to the questions "During the past 12 months of working on the job, how many times did you lack the physical strength/endurance to complete a physically demanding task?"



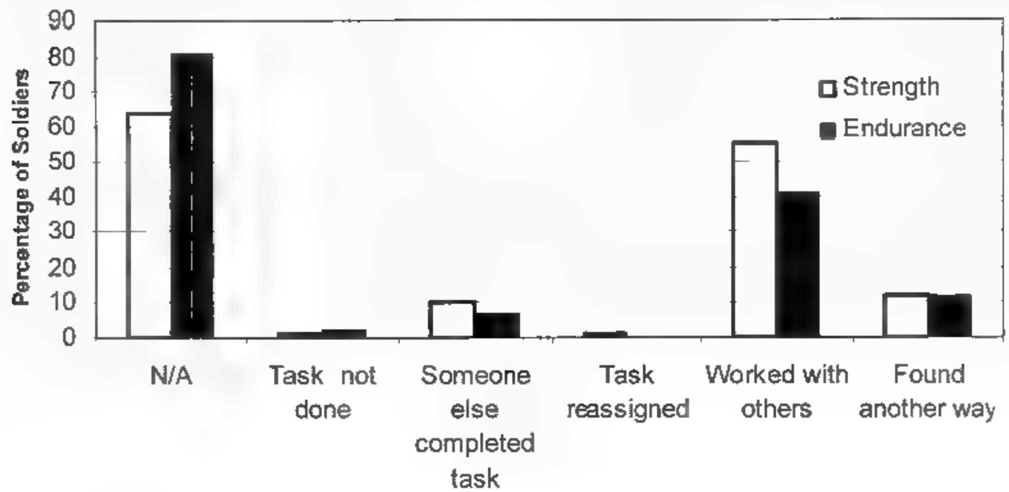
In terms of the impact on their ability to perform physically demanding tasks, (Figure 3) 75% reported lack of strength had no or minimal impact, while 85% reported lack of endurance had no or minimal impact. The remaining Soldiers (25% for strength, 15% for endurance) reported "some" or "significant impact," but none reported lack of strength or endurance as having a "major impact" on their ability to complete strength or endurance demanding tasks.

Figure 3. Reponses to "During the past 12 month, what impact has lack of? physical strength/endurance had on your ability to perform strength/endurance demanding work tasks?"



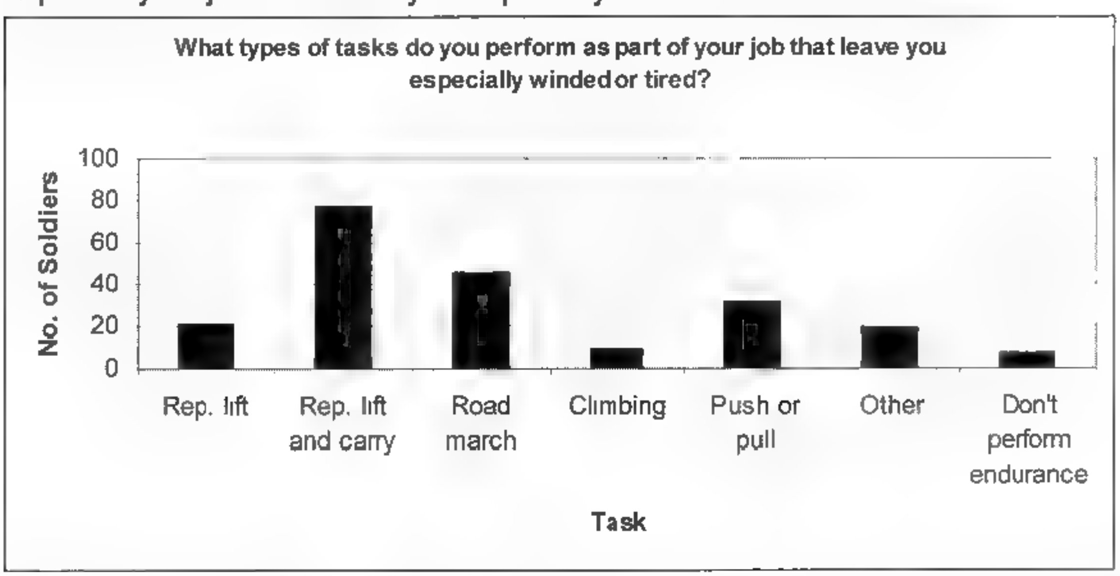
In two separate questions, Soldiers were asked "What generally happened if you lacked the strength (question 1) /endurance (question 2) to perform a physically demanding task?" Of those who did not respond that the question was not applicable, 39% reported they worked with others to perform strength demanding tasks, while 28% worked with others to perform endurance-related tasks (Figure 4). Fortunately, very few Soldiers reported that the task was not done. The remainder reported they found another way to complete the task or reported that someone else completed it. Very seldom was a task reassigned to another Soldier.

Figure 4 Response to "What generally happened if you lacked the strength (question 1) /endurance (question 2) to perform a physically demanding task?"



Soldiers were provided a list of activities and responded to the question "What types of tasks do you perform as part of your job that leave you especially winded or tired?" Soldiers could check off more than one item and were allowed to write in additional activities. These responses are illustrated in Figure 5. Repetitive lifting and carrying was cited as an activity that left 54% of the Soldiers winded and tired. The next most cited activities were road marching (32%), and pushing/pulling (22%).

Figure 5. Frequency distribution of responses to "What types of tasks do you perform as part of your job that leave you especially winded or tired?"



Soldiers were asked to rate how strongly they agreed or disagreed with a series of statements. The statements and the frequency distribution of the responses are

shown in Table 22. Most Soldiers agreed they had adequate strength (94%) and endurance (64%) to get the job done most of the time, but 5% thought strength was a problem and 22% thought endurance was a problem for themselves or their team's mission. This was somewhat inconsistent with responses earlier in the questionnaire, where 42% of Soldiers reported having one or more times when they lacked the physical strength and 40% reported having one or more times when they lacked the endurance to perform their job. Based on the ergonomic analysis of the job, it was expected that strength demands would present a greater problem than endurance activities, but this is not what was reported by the Soldiers. Additional figures illustrating data from the Physical Demands Self-Evaluation of MOS 63B Questionnaire can be found in Appendix H.

Table 22. Frequency distribution of responses to statements on the adequacy of strength and endurance to perform 63B job (%=percentage of sample)

	Strongly disagree		Disagree		Neither agree nor disagree		Agree		Strongly Agree	
	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%
Most of the time I have adequate strength to get the job done.	4	2.8	1	0.7	4	2.8	66	45 8	69	47.9
Lack of physical strength in our work team rarely keeps us from successfully performing our mission.	4	2.8	3	2.1	3	2.1	68	47 2	66	45.8
Most of the time I have adequate endurance to get the job done	14	9 7	17	11.8	21	14.9	55	38 2	37	25.7
Lack of endurance in our work team rarely keeps us from successfully performing our mission.	14	9.7	17	11 8	23	16.0	51	35 4	39	27.1

CORRELATIONS BETWEEN MECHANIC TASK PERFORMANCE AND DESCRIPTIVE VARIABLES

Table 23 lists the correlations between the total task times (without rest) and physical descriptors. Age and rank were negatively correlated with all four task times indicating that the older and higher ranking Soldiers completed the task more quickly. All measures of body size and composition, with two exceptions, were negatively correlated with the four task times. This indicates that bigger individuals (be it height, weight, quantity of body fat, or muscle mass) tended to perform the tasks faster than smaller Soldiers. It should be noted that the correlations between task time and body fat measurements were the lowest. Two exceptions to the relationship between body size and task performance were the correlation between height and starter replacement

time (r=-0.16, p=.07) and between fat mass (kg) and tire change (r=-0.11, p=.17). The starter is replaced while lying supine, so height is not an advantage in performing this task. It is not clear why fat mass would be related to the other tasks, but not tire change. Percent body fat was only weakly correlated with alternator repair time, and not to the other three tasks.

Table 23. Correlation between total task performance times (without rest) and physical descriptors.[1]

	Alternator Repair Time (min)	Battery Change Time (min)	Starter Replacement Time (min)	Tire Change Time (min)
Age (yrs)	**-.30**	**-.27**	**-.25**	**-.21**
	N=144	N=144	N=129	N=144
	p=.00	p=.00	p=.01	p=.01
Rank	**-.34**	**-.36**	**-.33**	**-.29**
	N=144	N=144	N=129	N=144
	p=.00	p=.00	p=.00	p=.00
Height (cm)	**-.20**	**-.21**	-.16	**-.23**
	N=144	N=144	N=129	N=144
	p=.02	p=.01	p=.07	p=.01
Weight (kg)	**-.23**	**-.27**	**-.28**	**-.24**
	N=144	N=144	N=129	N=144
	p= 01	p= 00	p=.00	p=.00
Fat Mass (kg)	**-.21**	**-.21**	**-.19**	-.12
	N=144	N=144	N=129	N=144
	p=.01	p=.01	p=.03	p=.17
FFM (kg)	**-.17**	**-.24**	**-.27**	**-.26**
	N=144	N=144	N=129	N=144
	p=.04	p=.00	p=.00	p=.00
Body Fat (%)	**-.17**	-.13	-.12	-.01
	N=144	N=144	N=129	N=144
	p=.04	p=.13	p=.19	p=.90

[1]Bolded correlations are significant at p<0.05 level.

Table 24 lists the correlations between task performance times and strength. The two measures of dynamic strength, bench press and IDL, and isometric handgrip strength, were significantly related to all but the alternator task. Heavy lifting (similar to IDL) is involved in all tasks except the starter replacement, which is a lift more similar to a bench press movement. High forces and torques are produced while using hand tools during all of the tasks, so it is somewhat surprising that handgrip strength was not significantly related to all four tasks. The alternator task tended to have the lowest correlations with all the strength measurements. The only strength measures significantly related to alternator task time were elbow extension and leg extension.

Battery change and tire change tasks had similar strength requirements as they were both significantly related to most of the thirteen strength measurements. Elbow

flexion was significantly related to battery change only. The battery change task involved a forward bend and reach to grasp the battery, which was then lifted up (elbow flexion movement) and out of the vehicle.

Elbow and leg extension (both left and right sides) were significantly correlated with all four tasks. This may have been due to the common requirement to push heavy items into place using the arms and legs. The exception to this is the starter replacement task, which does not involve the lower body, except if the knee is used to stabilize the starter while securing it to the engine block.

Table 24. Correlation between total task performance times (without rest) and muscle strength .

	Alternator Repair Time (min)	Battery Change Time (min)	Starter Replacement Time (min)	Tire Change Time (min)
Bench Press (kg)	-.03	**-.19**	**-.20**	**-.18**
	N=142	N=142	N=128	N=142
	p=.75	p=.02	p=.02	p=.03
IDL(kg)	-.10	**-.24**	**-.26**	**-.32**
	N=142	N=142	N=127	N=142
	p=.22	p=.00	p=.00	p=.00
Hand Grip (kg)	-.11	**-.26**	-.17	**-.34**
	N=144	N=144	N=129	N=144
	p=.19	p=.00	p=.06	p=.00
Back Extension (kg)	-.08	**-.24**	-.13	**-.31**
	N=144	N=144	N=129	N=144
	p=.34	p=.00	p=.15	p= 00
Rt Elbow Extension (kg)	**-.19**	**-.20**	**-.33**	**-.24**
	N=144	N=144	N=129	N=144
	p=.02	p=.02	p=.00	p=.00
Lt Elbow Extension (kg)	**-.21**	**-.20**	**-.35**	**-.27**
	N=144	N=144	N=129	N=144
	p=.01	p=.02	p= 00	p=.00
Rt Elbow Flexion (kg)	.07	**-.26**	-.01	-.13
	N=144	N=144	N=129	N=144
	p=.39	p=.00	p=.95	p=.12
Lt Elbow Flexion (kg)	.02	**-.29**	-.00	-.14
	N=144	N=144	N=129	N=144
	p=.79	p=.00	p=.98	p=.09
Shoulder Flexion (kg)	.08	**-.27**	-.01	**-.19**
	N=143	N=143	N=129	N=143
	p=.32	p= 00	p=.90	p=.02
Rt Leg Extension (kg)	**-.17**	**-.19**	**-.18**	**-.31**
	N=142	N=142	N=127	N=142
	p=.05	p=.02	p=.04	p=.00
Lt Leg Extension (kg)	**-.17**	**-.20**	**-.27**	**-.31**
	N=142	N=142	N=127	N=142
	p=.05	p=.02	p=.00	p=.00
Rt Leg Flexion (kg)	-.03	-.11	-.15	**-.21**
	N=142	N=142	N=127	N=142
	p=.73	p=.21	p=.09	p= 01
Lt Leg Flexion (kg)	-.13	-.14	**-.23**	**-.20**
	N=142	N=142	N=127	N=142
	p=.12	p=.11	p=.01	p=.02

[1]Bolded correlations are significant at $p<0.05$ level.

The correlations between task performance times and scores on the APFT are listed in Table 25. With the exception of the alternator repair task, which was significantly related to sit-ups and push-ups, none of the tasks were significantly related to performance on the APFT. The alternator task appears to have different physical requirements than the other tasks, as evidenced by the differences in correlations with both muscle strength and the APFT test items. A positive correlation between APFT items and Alternator repair time indicates that superior APFT performance was associated with increased, or poorer, task completion time. The reasons for this are not clear. Correlations between task component times and physical descriptors can be found in Appendix I.

Table 25. Correlations between task performance time (no rest) and the Army Physical Fitness Tests items.

	Alternator Repair Time (min)	Battery Change Time (min)	Starter Replacement Time (min)	Tire Change Time (min)
Sit-up (# in 2 min)	**.17**	.16	.06	.07
	N=144	N=144	N=129	N=144
	p=.04	p=.06	p=.47	p=.44
Push-up (# in 2 min)	**.27**	.05	.09	-.01
	N=144	N=144	N=129	N=144
	p=.00	p=.55	p=.32	p=.93
2 mile Run Time (min)	-.15	-.02	-.04	-.00
	N=112	N=112	N=106	N=112
	p=.12	p=.87	p=.71	p=.98

[1]Bolded correlations are significant at p<0.05 level.

CORRELATIONS BETWEEN MECHANIC TASK PERFORMANCE AND SUBJECTIVE RATINGS OF TASK PERFORMANCE

The correlations between task performance time and questions asked during the task performance are listed in Table 26. The frequency of task performance did not have a strong influence on task performance time, nor did when the task was last performed relate to task performance time. The three questions regarding the Soldier's skill ratings (pre- and post-task) and performance ratings were all significantly correlated with performance time. The correlations with skill ratings were slightly higher after task performance, presumably because Soldiers were able to more accurately assess their skill The positive correlations between skill ratings and time indicate those with better self-ratings of skill took less time to complete the task These results indicate that Soldiers were able to assess their ability or skill to some extent, especially after the task was completed.

Table 26 Task performance and subjective rating correlations

	Alternator Repair Time (min)	Battery Change Time (min)	Starter Replacement Time (min)	Tire Change Time (min)
Task Frequency	02	-07	.08	.03
	N=144	N=144	N=129	N=144
	p= 86	p=.39	p= 36	p=.75
Task Last Performed	.11	-03	**.20**	.02
	N=144	N=144	N=129	N=144
	p=.19	p=.69	p= 03	p=.85
Skill Rating (pre-task)	**.24**	**.23**	**.32**	**.24**
	N=144	N=144	N=129	N=144
	p= 00	p=.01	p=.00	p=.00
Skill Rating (post-task)	**.41**	**.32**	**.56**	**.40**
	N=144	N=144	N=129	N=144
	p=.00	p=.00	p=.00	p= 00
Performance Rating (post-task)	**.50**	**.29**	**.48**	**.35**
	N=144	N=144	N=129	N=144
	p=.00	p= 00	p= 00	p=.00
Lift/Lower out to Remove (RPE)	.05	14	00	-.00
	N=144	N=144	N=129	N=144
	p=.56	p=.09	p=.97	p= 96
Lift in to Replace (RPE)	09	.12	.08	.04
	N=144	N=144	N=129	N=144
	p=.29	p=.17	p= 38	p= 63
Position/Hold RPE	**.30**	N/A	**.29**	**.18**
	N=144	N/A	N=129	N=144
	p=.00	N/A	p= 00	p= 03
Overall RPE	08	-01	**.22**	10
	N=141	N=144	N=128	N=143
	p=.33	p=.91	p=.01	p= 26

[1]Bolded correlations are significant at p<0.05 level.

RPE for positioning and holding was significantly and positively correlated with the three tasks containing this component of performance (Alternator, Starter, and Tire Tasks). It was expected that overall RPE and RPE for lift/lower of heavy objects in and out of the vehicle would be significantly correlated with performance time, but this was not the case.

CORRELATIONS BETWEEN MECHANIC TASK PERFORMANCE AND PHYSICAL ACTIVITY QUESTIONNAIRE ITEMS

The correlations between task performance and responses to the Physical Activity Questionnaire items are listed in Table 27 Aerobic training and sports participation were not related to task performance times. The Tire and Alternator tasks were each significantly related to a measure of strength training physical activity, but not

in the expected direction. One would expect a negative relationship, indicating reduced task performance time with increased strength training (frequency or time). In the case of the tire change and alternator repair, performance time increased with increased physical activity. It is possible that these were spurious correlations Time in MOS, a measure of experience, was significantly and negatively correlated with all four task times, as was rank (Table 27). Soldiers with more experience on the job tend to perform the mechanics tasks more rapidly.

Table 27. Task performance and self-reported physical activity correlations.

	Alternator Repair Time (min)	Battery Change Time (min)	Starter Replacement Time (min)	Tire Change Time (min)
Aerobic Training (days/week)	.11	-.03	09	.08
	N=144	N=144	N=129	N=144
	p=.18	p=.71	p=.33	p= 34
Aerobic Training (min/day)	05	-.04	- 00	-.03
	N=144	N=144	N=129	N=144
	p=.56	p=.68	p=.99	p= 70
Play Sports (days/week)	03	.07	-.01	-.03
	N=144	N=144	N=129	N=144
	p=.69	p=.42	p=.91	p=.74
Play Sports (min/day)	.03	.04	.03	-.13
	N=144	N=144	N=129	N=144
	p=.71	p= 67	p= 72	p= 12
Strength Training (days/week)	12	.11	.07	**.23**
	N=144	N=144	N=129	N=144
	p=.16	p=.19	p=.45	p= 01
Strength Training (min/day)	**.18**	-.03	.10	-.01
	N=144	N=144	N=129	N=144
	p=.03	p=.69	p= 26	p= 88
Overall Physical Activity	-.09	03	06	- 08
	N=144	N=144	N=129	N=144
	p= 29	p=.76	p=.47	p= 34
Time in MOS	**-.32**	**-.29**	**-.32**	**-.26**
	N=144	N=144	N=129	N=144
	p=.00	p=.00	p=.00	p= 00

[1]Bolded correlations are significant at p<0.05 level.

PREDICTION OF 63B TASK PERFORMANCE

A number of analyses were conducted to develop prediction equations for task completion time. The descriptive and subjective variables most highly correlated with task completion time were used in a series of forward and backward stepwise multiple regression analyses. Although a number of regression equations were developed, none accounted for more than 25% of the variance in the task time, and all had extremely large standard errors of the estimate (SEE). The equations are listed in Table 28.

Table 28. Forward and backward stepwise regression equations derived to predict task performance time.

Task & Direction	Predictive Equation	R	R^2_{ADJ}	SEE[1] (sec)
Alternator[a] Forward	=1351.6 - 98.6* Rank + 5 2* PU - 11.3* EEL	.450	.186	396
Alternator[a] Backward	=1285.3 - 89.4* Rank + 79.9* ARR – 12.7*EEL– 5.2* SU + 9 0* PU	.492	.214	393
Battery[b] Forward	= 1252.9 – 56 8* Rank -1.1* BE -5.8* EFL	.456	.191	204
Battery[b] Backward	= 1886.4 -55 2*Rank -4.6*Height -6 8*SF	.447	.182	205
Starter[c] Forward	=930 7 – 18.9* EEL – 199 3* Rank + 51 4* SHRPE + 23 6* Age	.511	.240	467
Starter[c] Backward	=1167 7 + 20 0* Age -189 2* Rank -13.8* EEL + 50 8* SHRPE - 3.1*LFL	.526	.251	463
Tire[d] Forward	=1030 8 -1 4* HG -35.8* Rank +13 4* TPRPE -1 0* BE	.495	.223	147
Tire[d] Backward	=1066 5 -36.4* Rank +2.4*BP -3 3*IDL +12.6*TPRPE -1.6* HG - 0.9*BE	.532	.251	144

[1]Standard error of the estimate

[a]Variables included in alternator analysis. age, rank, height, weight, alternator repair rating (ARR), elbow extension-left (EEL), right leg extension strength, sit-up (SU), push-up (PU), time in MOS

[b]Variables included in battery analysis. age, rank, height, weight, battery repair rating (BRR), bench press, incremental dynamic lift, hand grip, back extension (BE), elbow extension left (EEL), elbow flexion-left (EFL), shoulder flexion (SF), leg extension-left, time in MOS

[c]Variables included in starter analysis: Age, rank, weight, bench press, incremental dynamic lift, elbow extension-left, leg extension-left, leg flexion-left, time in MOS, starter repair rating (SRR), starter hold RPE (SHRPE), leg flexion-left.

[d]Variables included in tire analysis. age, rank, bench press (BP), incremental dynamic lift (IDL), elbow extension-left, leg extension-left, time in MOS, heigh-, total lean mass, tire change rating, tire position RPE (TPRPE), handgrip (HG) back extension(BE), shoulder flexion, leg flexion right, sports days per week

In order to equate the tasks times, the four total task times were standardized (z-scores), summed, and correlated with the predictive variables. The significant correlations are listed in Table 29.

Table 29. Correlations between the sum of standardized task times (z-scores) and descriptive measurements.

Predictive Variable	r	N	p-value
IDL (kg)	0.26	142	.002
Handgrip (kg)	.22	144	.007
Back Extension (kg)	.20	144	.014
Elbow Extension-right (kg)	.26	144	.001
Elbow Extension-left (kg)	.31	144	.000
Leg Extension- right (kg)	.25	142	.003
Leg Extension- left (kg)	.27	142	.001
Leg Flexion- left (kg)	.21	142	.014
Push-up (#)	-.18	144	.033
Age (yrs)	.29	144	.000
Rank	.37	144	.000
Height (cm)	.24	144	.004
Weight (kg)	.29	144	.001
Fat Mass (kg)	.19	144	.040
Lean Mass (kg)	.27	144	001

A forward-stepwise multiple regression analyses was done to predict the sum of the four task z-scores using Rank, Elbow Extension-left, and Leg Extension-Left as predictors. The following equation was produced:

Sum Z-scores=-13 + 1.14 (Rank) + 0.13 (Elbow Extension-Left)
R=.47, R^2=.20, Standard Error of the Estimate=399

As with previous attempts, the predictive capability of the equation was not high.

DISCUSSION

MECHANICS TASK PERFORMANCE

A primary purpose of this study was to determine if a representative sample of 63B Soldiers were able to perform the critical, physically demanding tasks of the MOS. The majority of Soldiers were able to complete all four tasks. The only task some Soldiers (9 men and 3 women) were not able to complete was the Starter task. There were no significant differences in measured variables (descriptive, strength, experience) between Soldiers who completed and failed to complete the starter task. Therefore, no recommendation can be made regarding prediction or identification of Soldiers who were most likely to fail at the starter task.

The overall task times were longest for the alternator and starter tasks due to longer install times. The alternator task was more technically complex than the starter task, but both required placement of a heavy object in a very precise position prior to fastening it to the engine block. Most Soldiers had performed the alternator and starter change tasks previously, but on a less frequent basis than they performed the battery and tire change tasks. The precision required to attach the motor parts, combined with the fact that Soldiers performed these tasks less frequently resulted in longer install and total task times. The other two tasks were less demanding in terms of object placement, and were more familiar to the Soldiers. Although the starter was not the heaviest of the four objects, it was perceived as the hardest task to complete based on overall RPE, as well as higher Lift/Raise and Position RPE ratings. To remove and install the starter, the Soldier laid supine under the HMMWV, while supporting the 55 lb starter with one hand or one knee. If the mechanic had difficulty placing the starter in the precise position, the starter weight had to be supported for an extended period of time. The required precision and dependence on upper body musculature likely led to the greater perceived effort for the starter task.

Soldiers rated their skill level to be similar before and after performing the tasks. Performing the task did not change their self-perception, and task time tended to be correlated with self-ratings. They had less confidence in their skill performing the starter task as compared to the other tasks, and this lower rating was validated by the longer task completion time, higher RPE, and lower success rate for starter replacement. The starter task was less familiar than the other tasks.

RPE for positioning and holding was significantly and positively correlated with performance time for the three tasks containing this component (alternator, starter, and tire tasks). It was expected that overall RPE and RPE for lift/lower of the heavy objects in and out of the vehicle would be significantly correlated with performance time, but this was not the case. Apparently, holding and positioning the object while securing it to the vehicle is a more important limiting factor to task performance time than is the ease of lifting/lowering the object, and is also a more important predictor of task performance time than the overall rating of exertion. A higher RPE for positioning and holding is likely the result of a lower skill level. A less skilled mechanic might be expected to have

greater difficulty and take more time to attain the precise position needed to attach the part to the vehicle.

A positive finding is that 63B Soldiers were confident in their ability to perform the tasks, rated themselves as skilled, and did not perceive significant problems related to strength and endurance. Although the majority of 63Bs reported having no problems performing the physically demanding tasks of their job, about 40% reported having had difficulty at least once in the previous year due to either strength or endurance issues. Repetitive lifting and carrying was cited as an activity that left 54% of the Soldiers winded and tired. The next most cited activities were road marching (32%), and pushing/pulling (22%). This is supported by previous reports of the most frequently performed soldiering tasks in both the British (30) and US Armies (39). Although strength was expected to be a greater limiting factor than endurance, more Soldiers perceived endurance tasks (22%) than considered strength tasks (5%) to be problematic in the accomplishment of their team's mission.

Women took longer than men to perform the battery and tire change tasks, but did not report a greater overall RPE. It is possible that women reported the same RPE because they took more time, and this equalized the overall physiological "strain" or exercise intensity. Although the number of women tested cannot be considered representative, the women 63Bs seemed able to perform their duties While it is unfortunate that few women volunteered to participate in this study, the results are encouraging in that most women were successful in completing all the tasks.

There were a number of significant correlations between task performance times and physical characteristics, muscle strength, or questionnaire items, however, the correlations were quite low. These Soldiers report a high level of physical training. The low correlations between muscle strength and task performance may indicate that the Soldiers are adequately trained for the MOS. This is supported by the MOS Physical Demands Questionnaire results indicating that Soldiers do not perceive significant problems related to strength or endurance. Age, rank, and time in MOS were negatively correlated with all four task times indicating that the older and higher ranking Soldiers completed the task more quickly, presumably due to greater experience and skill.

Nearly all measures of body size and composition were negatively correlated with the four task times. This indicates that bigger Soldiers tended to perform the tasks faster than smaller Soldiers. The loads moved and held in the process of performing the tasks represent a smaller percentage of a larger Soldier's weight or FFM, and would therefore be easier to manage. Percent body fat (proportional to body mass) was weakly correlated with alternator repair time, but not to the other three tasks. Percent body fat is normalized for body size, and is not a metabolically active tissue. Percent body fat was not expected to be highly related to task performance times, and this may have been a spurious finding.

APFT events had little to no relationship to mechanics task performance. This lack of relationship with the APFT has been reported previously for other soldiering tasks, such as load carriage and repetitive lifting (13,34). The low correlations between

strength measurements and task performance times were not expected. The multiple regression equations derived had a low predictive ability and a high standard error of the estimate. It may be that using time as a measure of 63B performance was inappropriate and did not adequately measure the skill of the Soldiers.

The one consistent finding was that rank was an important predictor of task performance. It was a significant predictor for all the tasks. 35% of the volunteers held the rank of SGT or above, while only 23% were Junior enlisted. This is in consonance with the reports for average time in MOS of 3 years or more. Rank is likely to be representative of both experience and skill. Presumably the highest ranking individuals have been successful and skilled performers in the MOS, and have likely been in the MOS longer than their lower ranking counterparts.

REPRESENTATIVE NATURE OF THE SAMPLE

A comparison of the measured characteristics of the 63B Soldiers with other samples of Soldiers and civilians will be presented to support the representative nature of the sample of men in terms of body size and composition, muscle strength and physical activity patterns. It is acknowledged that nine women cannot be considered representative of all women 63Bs, but comparison data will also be presented for women.

Body Composition

Table 30 contains comparison body size data for several samples of Soldiers including Basic Combat Trainees, Infantrymen, and two groups of active duty Soldiers from a variety of MOSs. The 63B Soldiers were older and tended to weigh more than previous samples of Basic Combat Trainees (27,36,37,46) and Infantrymen (18). When compared to 21-27 year old active duty Soldiers (12) measured in 1983, the 63B men weighed 9% more and the 63B women weighed 13% more. The 63B women tended to have a higher percent body fat and similar fat free mass (FFM) when compared to a 1998 sample of female Basic Combat Trainees (37). The male 63Bs had a higher percent body fat (2.7%) and tended to have less FFM (2 kg) than male Basic Combat Trainees (37). When compared to a recent sample of male infantry solders of similar age (Ft. Polk, unpublished data, 2006), the 63B men weighed 2 kg less on average, and tended to have a slightly higher percent body fat and lower FFM. The BMI of the 63Bs was greater than that of active duty Soldiers from 1983 (12), but lower than a large group of male and female Soldiers measured in 2000 and 2002 (6). A BMI of >25 kg/m^2 is considered overweight, therefore, the average Soldier in this study was overweight. These data support reports of increasing weight and BMI over time in the general US population (26). The height, weight, and body composition of the 63B Soldiers was not dramatically different from recent samples of active duty Soldiers, so the sample of men may be considered representative of the population in terms of height, weight and body composition.

Table 30. Comparison of height, weight and body composition with previous samples of Soldiers.

Sample (year)	Height (cm)		Weight (kg)		BMI (kg/m^2)		Body Fat (%)		Fat Free Mass (kg)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Active Duty[1,2] 1983 (12)	174.0± 6.8 (n=389)	162 4± 6.4 (n=155)	74.2± 10 6 (n=389)	59 5± 8.1 (n=155)			18 0 ±6 5 (n=389)	27.0± 5 9 (n=155)	60 5± 7.4 (n=389)	43 1± 5.0 (n=155)
Infantry 1989[3] (18)	177 6± 7 5	NA	77.0± 10.0	NA			15 9± 4 5	NA	64.4± 7.9	
Post-BCT 1998 (36)	176 5± 7.0 (n=182)	163.0± 6.1 (n=168)	76.8 ± 11.2 (n=182)	62 8± 9 4 (n=168)			14 4± 5 5 (n=182)	25.6± 5 2 (n=168)	65.2± 8.0 (n=182)	46 3 ±5 7 (n=168)
Active Duty[3] 2002-04 (5)	176.5± 6 9 (n=1521)	163 3± 6.2 (n=1257)	81.3± 12.2 (n=1521)	65 6± 10.2 (n=1257)	26.1±3.4 (n=1521)	24 6±3 3 (n=1257)	16 9± 5 9 (n=1521)	28 6±7 3 (n=1257)	Not reported	Not reported
Infantry[4] 2006	177 2± 7 1 (n=229)	NA	82.5± 13 8 (n=229)	NA	26 2±3 7 (n=229)	NA	18 2± 6 3 (n=229)	NA	65.4±7 6 (n=229)	NA
63B Soldiers	176 1± 6 6	161 5±6 2	80 8±13.1	67.5±11.4	26 1±3 8	25 7±3 0	19.4±6.1	32.0±5.7	63 3±8 0	44.6±5.3

[1]21- 27 year old Soldiers.
[2]Hydrostatic weighing
[3]Circumference using Department of Defense equation.
[4]Ft. Polk, unpublished data, 2006
NA=not applicable

Muscle Strength

Table 31 contains comparison muscle strength data for several samples of Soldiers and bench press normalized for body weight from a large sample of civilians (3). The lifting strength of the 63B men was comparable to a recent sample of 229 Infantrymen (Ft. Polk, unpublished, 2006). When the bench press strength relative to body weight (BP kg/BW kg) of the 63B Soldiers is compared to a large sample of 20-29 year old civilian men and women (3), the 63B Soldiers were comparable to the 50th percentile man and woman. It should be noted that the civilian sample was measured using a Universal bench press machine, rather than free weights. The handgrip strength was nearly identical to that obtained in a large sample of men and women at the end of Initial Entry Training (41), but was 12% less than a group of Infantry Soldiers (18). The back extension strength of male 63Bs was also 5% lower than that of the Infantry Soldiers. It has been shown that Soldiers do not consider the physical requirements of an MOS prior to enlistment (41), and this appears to be true of 63B Soldiers, since they do not appear to be stronger than other groups of age-matched Soldiers and civilians. It does appear, however, that they are representative of the population in terms of muscle strength.

Table 31. Comparison of 63B strength to previous samples of soldiers and civilians.

Sample	Incremental Dynamic Lift (kg)		Bench Press (weight lifted/body mass)		Handgrip (kg)		Back Extension Strength (kg)	
	Men	Women	Men	Women	Men	Women	Men	Women
Civilian (3)			1.06*	0.65*				
Post-AIT, 1982 (41)					52 6±7.7 (n=465)	33.7±5.6 (n=487)		
Infantry, 1989 (18)					60.0±10.0 (n=81)	NA	88.0±14.0 (n=79)	NA
Post-AIT,1995 (32)	79.4± 13.0 (n=23)	39 8 ± 6.6 (n=17)						
Infantry (2006)	72.9±13.7 (n=226)	NA						
63B Soldiers	71.3±12.7	38.8±5.1	1.05	0.66	52.7±8.5	33.3±7.6	83.1±14.7	52.1±8.0

*50th Percentile for 20-20 year olds

PHYSICAL ACTIVITY

The 63B Soldiers reported a high activity level in terms of aerobic and strength training. 80% performed aerobic training, and 62% performed strength training 3 or more days/week. The responses of the 63B men to the Physical Activity questionnaire were compared to a sample of male Soldiers who completed a similar questionnaire at the beginning of basic combat training (BCT) in Table 32. The new recruits were asked about their activity level just prior to entering the Army (21,22). 63B males reported significantly higher activity levels than the basic combat trainees (Table 31). A similar questionnaire was given to a group of Infantry Soldiers (Ft. Polk, unpublished data, 2006). Similar to the 63B Soldiers, 88% of Infantry Soldiers reported performing aerobic exercise 3 or more days/week, and 66% reported performing strength training exercise 3 or more days/week. While this high level of physical activity among active duty Soldiers is a positive finding from a public health standpoint, the 63Bs were 5 kg heavier than the basic trainees (21,22). It does appear that the 63B men are representative of typical active duty Soldiers in terms of their level of physical activity.

Table 32. Comparison of Physical Activity questionnaire responses and descriptive variables between current 63B males and large sample of men entering basic combat training at Ft. Jackson, 1998.

	63B Study (men)	Basic Combat Trainees (men, n=188)
Variable	Mean ± SD	Mean ± SD
Age[1]	25.5 ± 6.0	21.4 ± 3.8
Height (cm)	176.1 ± 6.6	175.6 ± 11.9
Weight (kg)[1]	80.8 ± 13.1	75.1 ± 13.9
Aerobic (days/week)[1]	4.1 ± 0.8	1.5 ± 1.0
Strength (days/week)[1]	3.8 ± 0.9	1.4 ± 0.9
Sports (days/week)[1]	2.5 ± 1.2	1.6 ± 1.1
Overall Physical Activity[1]	2.2 ± 0.9	1.5 ± 1.0

[1]Significant difference between 63B study and Basic Combat Trainees ($p<0.05$)

LIMITATIONS

A significant limitation of this study was the low number of women volunteers. Anecdotal reports of women not able to perform various physically demanding tasks, as well as the high injury and hospitalization rates for MOS 63B, were key factors in the decision to conduct this study. One goal was to determine if there was a performance difference between men and women and to identify what percentage of 63B Soldiers (both male and female) were physically capable of performing some of the common strength demanding tasks of the MOS. Based on the limited available data, women were slower to complete two of the tasks, but most were able to perform these tasks. In

addition, strength was not often reported to be a limiting factor. Surprisingly, more Soldiers reported aerobic endurance-related problems than muscle strength-related problems.

A second limitation to this study was the use of time as a performance measure, although there was no alternative that was clearly superior. One of the alternatives considered was to film all the tasks and then have a SME score the performances. This scoring method was not selected due to concerns that Soldiers would be less likely to volunteer if they thought they would be graded by a senior NCO. In addition, it was not clear that this could be done in an objective manner. A second alternative was to determine the maximum acceptable load for completing a task. This option was rejected because it was not realistic and would have required considerably more time to complete

CONCLUSIONS

1. Most Soldiers were capable of performing the strength demanding tasks of their MOS.

2. Although women performed two of the tasks more slowly than men, and rated portions of the tasks as requiring more effort, they were able to complete the tasks satisfactorily.

3. The requirement to position and hold heavy engine parts during task performance was perceived as more difficult than the requirement to lift/lower the engine parts.

4. More-experienced 63Bs (as evidenced by age, rank, or time in MOS) were able to complete the tasks more quickly than less-experienced Soldiers.

5. The alternator task tended to have fewer and different relationships with the strength and APFT variables than the other tasks, possibly indicating a higher skill requirement.

6. The correlations between task performance, strength, APFT scores, and descriptive variables were low. These low correlations provide little direction for the development of physical training programs for 63Bs.

7. The predictive equations developed did not adequately account for the variability in task performance and could not be used to select skilled mechanics.

RECOMMENDATIONS

Although there were few women in this study, we demonstrated that most mechanics (men and women) were able to perform several of the most common, physically demanding tasks performed by 63Bs. Soldiers do not perceive lack of strength to have a significant impact on the performance of their job tasks. The relatively low correlations between strength and performance tend to indicate that the current physical training is adequate for job performance. The most important and common predictor or 63B performance was rank, so administrative efforts should be made to retain skilled mechanics in the MOS.

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APPENDIX A: PRE- & POST-TASK QUESTIONS

Questions asked of Soldiers before and after performance of each task

Prior to task performance:

1. Typical frequency of task performance:
   Daily 3-4 x/week 1-2 x/week 2-3 x/month monthly <monthly

2. When was the last time you performed this task? Date____________
   within past week within past month within past 6 months
   within past year never other___________

3. Rate how well you think you will perform on this (battery, starter, alternator, or tire) change task:
   Excellent Good Average Fair Poor

Following task performance:

1. Compared to others within your company, how well would you rate your skill at this task?
   Expert Very Good Average Moderate In-training Novice

2. Rate how well you did perform on this (battery, starter, alternator, or tire) task:
   Excellent Good Average Fair Poor

APPENDIX B: PHYSICAL DEMANDS SELF-EVALUATION OF MOS 63B

Subject Number ________________ SSN________________________

1. What is your paygrade?

E-1	E-5
E-2	E-6
E-3	E-7
E-4	E-8

2. What is your gender? Male__________ Female__________

3. How long have you been assigned to work in a 63B position?
   ________ Less than 1 year
   ________ At least 1 year, but less than 2 years
   ________ At least 2 years, but less than 4 years
   ________ At least 4 years, but less than 8 years
   ________ More than 8 years (specify ________ years)

An **over-exertion injury** is a physical injury that may or may not require medical attention that resulted because you tried to perform a work-related task that exceeded your physical capacity This might occur from sudden and unexpected loading, for example, if you tried to stop a large object from falling, or tried to lift an object that was heavier than you expected it to be.

4 During the past 12 months, how often have you been unable to perform the full range of your duties because of a work-related **over-exertion injury**?
   ________ Never
   ________ 1 or 2 times
   ________ 3 or 4 times
   ________ 5 to 6 times
   ________ More than 6 times

5 During the past 12 months, how have **over-exertion injuries** affected your ability to perform your job?
   ________ I have had no over-exertion injuries
   ________ Over-exertion injuries did not impact my job performance
   ________ My injuries resulted in 8 hours or less of lost or reduced job productivity
   ________ My injuries resulted in more than 8 hours of lost or reduced job productivity

7 During the past 12 months, how much additional work were you or your co-workers expected to perform because another co-worker experienced an **over-exertion injury**?
   ________ No over-exertion injuries occurred
   ________ No additional work in spite of over-exertion injuries
   ________ Less than 8 hours additional work
   ________ 8-16 hours additional work
   ________ 17-40 hours additional work
   ________ More than 40 hours additional work

8 During the past 12 months of working on the job, how many times did you lack the **physical strength** to complete a physically demanding individual task? For example you were physically unable to lift an object Include only individual tasks not those typically performed as a team task

________ Never
________ 1-3 times
________ 4-10 times
________ 11-20 times
________ More than 20 times

9 During the past 12 months, what impact has lack of **physical strength** had on your ability to perform **strength demanding work tasks**?

________ No impact; my physical strength has been sufficient to perform all strength demanding work tasks
________ Minimal impact; I perform almost all strength demanding tasks with little difficulty
________ Some impact; I perform most strength demanding tasks with little difficulty
________ Significant impact; I have difficulty performing many strength demanding tasks
________ Major impact; I have difficulty performing most strength demanding tasks

10 What generally happened if you lacked the **physical strength** to perform a physically demanding individual task?

________ Not applicable, I have always had the physical strength to perform physically demanding tasks.
________ The task was not done.
________ I got someone else to complete the task
________ My supervisor assigned the task to someone else.
________ I worked with one or more individuals and/or equipment (tools) to perform the task.
________ I found another way to complete the tasks satisfactorily which did not require other individuals.

Endurance is defined as the ability to continue working without becoming overly tired or winded It is related to long term or repetitive tasks such as loaded rucksack marching or loading a truck, and not necessarily related to strength

11. During the past 12 months of working on the job, how many times did you lack the **endurance** to complete a physically demanding individual task (you became especially winded or tired)? Include only individual tasks not those typically performed as a team task

________ Never
________ 1-3 times
________ 4-10 times
________ 11-20 times
________ More than 20 times

12 During the past 12 months, what impact has lack of **endurance** had on your ability to perform **physically demanding work tasks**?

________ No impact; my endurance has been sufficient to perform all physically demanding work tasks
________ Minimal impact; I perform almost all physically demanding tasks with little difficulty
________ Some impact; I perform most physically demanding tasks with little difficulty
________ Significant impact, I have difficulty performing many physically demanding tasks
________ Major impact; I have difficulty performing most physically demanding tasks

13 What generally happened if you lacked the **endurance** to perform a physically demanding individual task?

________ Not applicable, I have always had the endurance to perform my physically demanding tasks

________ The task was not done.
________ I got someone else to complete the task
________ My supervisor assigned the task to someone else
________ I worked with one or more individuals and/or equipment (tools) to perform the task
________ I found another way to complete the tasks satisfactorily which did not require other individuals.

14 What types of tasks do you perform as part of your job that leave you especially winded or tired?

________ Repetitive lifting
________ Repetitive lifting-and-carrying tasks
________ Road marches
________ Climbing tasks
________ Pushing or pulling tasks
________ Other Please specify ____________
________ I don't perform any endurance type tasks

Please rate how strongly you agree or disagree with the following statements:

15 Most of the time I have adequate strength to get the job done

1 Strongly agree 2 Agree 3 Neither agree nor disagree 4 Disagree 5 Strongly disagree

16 Lack of physical strength in our work team rarely keeps us from successfully performing our mission.

1 Strongly agree 2 Agree 3 Neither agree nor disagree 4 Disagree 5 Strongly disagree

17 Most of the time I have adequate endurance to get the job done.

1 Strongly agree 2 Agree 3 Neither agree nor disagree 4 Disagree 5 Strongly disagree

18 Lack of endurance in our work team rarely keeps us from successfully performing our mission

1 Strongly agree 2 Agree 3 Neither agree nor disagree 4 Disagree 5 Strongly disagree

19 Identify the three tasks that require the most strength in your job Please be specific and identify the objects/equipment involved in the tasks.

a

b

c.

20 Identify the three tasks that require the most endurance in your job Please be specific and identify the objects/equipment involved in the tasks

a.

b

c

APPENDIX C: PHYSICAL ACTIVITY QUESTIONNAIRE

Subject number: ________________ SSN______________________

On the following questions, rate how often you exercised on average IN THE LAST YEAR

1. AEROBIC EXERCISE
a. How many days per week did you perform aerobic (running, cycling, swimming, etc) in the last year on average?

___ None	___ 3-4 days/wk
___ Less than 1 day/wk	___ 5-6 days/wk
___ 1-2 days/wk	___ 7 days/wk

b. On days you performed aerobic exercise (running, cycling, swimming, etc) in the last year, how long did you exercise on average?

___ None	___ 31-45 min
___ Less than 15 min	___ 46-60 min
___ 16-30 min	___ More than 60 min

STRENGTH TRAINING

a How many days per week did you do exercise to improve your strength (free weights universal, nautilus, push-ups, sit-ups, etc.) in the last year?

___ None	___ 3-4 days/wk
___ Less than 1 day/wk	___ 5-6 days/wk
___ 1-2 days/wk	___ 7 days/wk

b On days that you performed exercise to improve your strength (free weights, universal, nautilus, push-ups, sit-ups, etc) in the last year, how long did you exercise on average?

___ None	___ 31-45 min
___ Less than 15 min	___ 46-60 min
___ 16-30 min	___ More than 60 min

3. SPORTS ACTIVITY

a How days per week did you participate in sports activities in the last year?

___ None	___ 3-4 days/wk
___ Less than 1	___ 5-6 days/wk
___ 1-2 days/wk	___ 7 days/wk

b On days that you performed sports in the last year, how long did you exercise on average?

___ None	___ 31-45 min
___ Less than 15 min	___ 46-60 min
___ 16-30 min	___ More than 60 min

4. OVERALL PHYSICAL ACTIVITY Overall, how would you rate yourself as to the amount of physical activity you perform, compared to others of your age and sex?

___ Much more active
___ Somewhat more active
___ About the same
___ Somewhat less active
___ Much less active

5. APFT: WHAT IS YOUR MOST RECENT ARMY PHYSICAL FITNESS TEST SCORE?

	Points	OR	Raw Score
Sit-up	________		________
Push up	________		________
2 mile run	________		________
Total	________		________

APPENDIX D: ALTERNATOR CHANGE FREQUENCY & SKILL RATING

Figure D-1. Alternator replacement task performance frequency

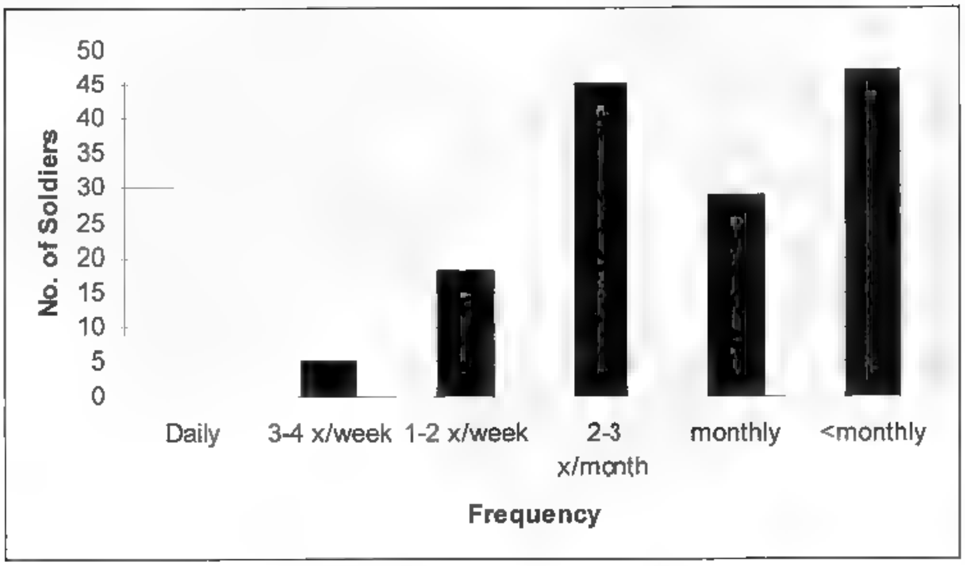


Figure D-2. Most recent alternator replacement task performance

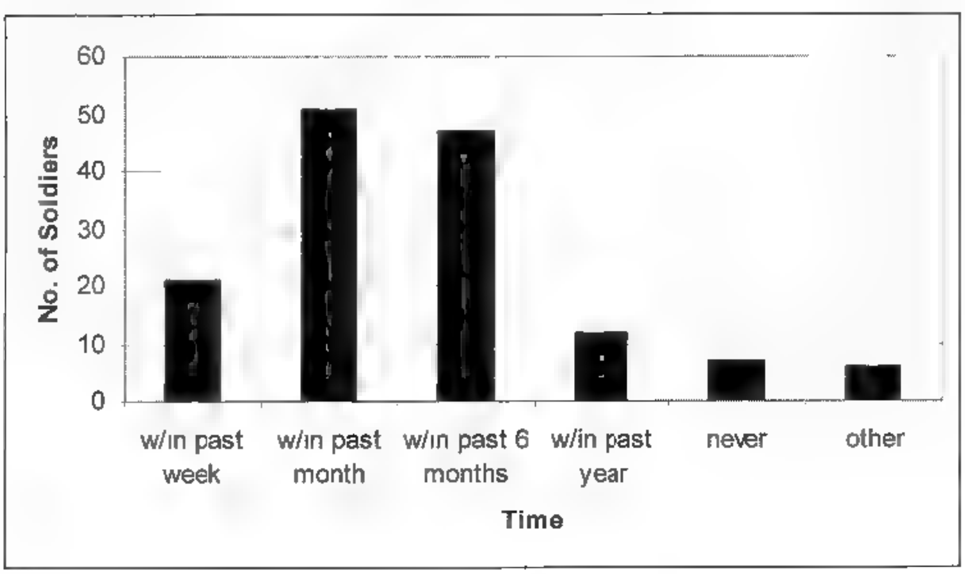


Figure D-3. Alternator replacement pre-task self rating

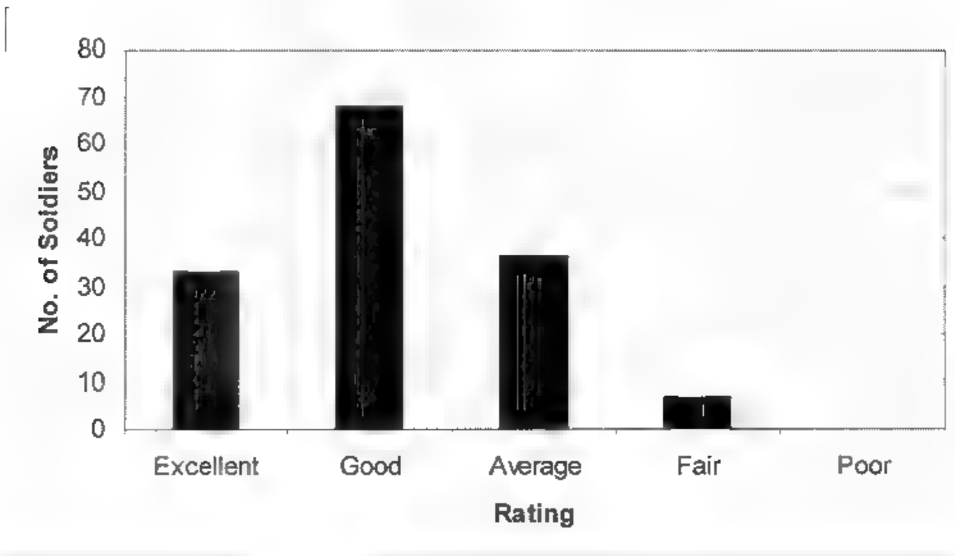


Figure D-4. Alternator replacement post-task performance self rating

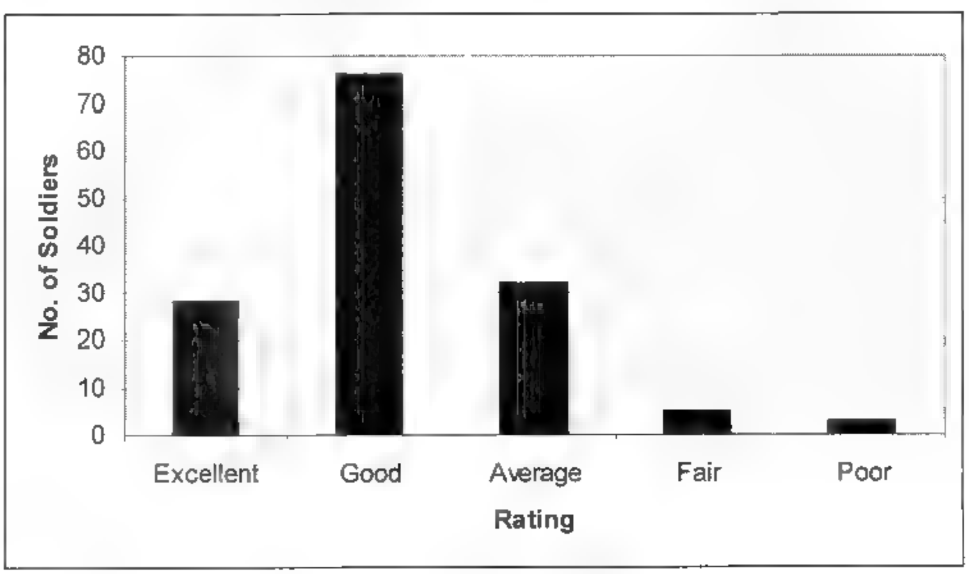
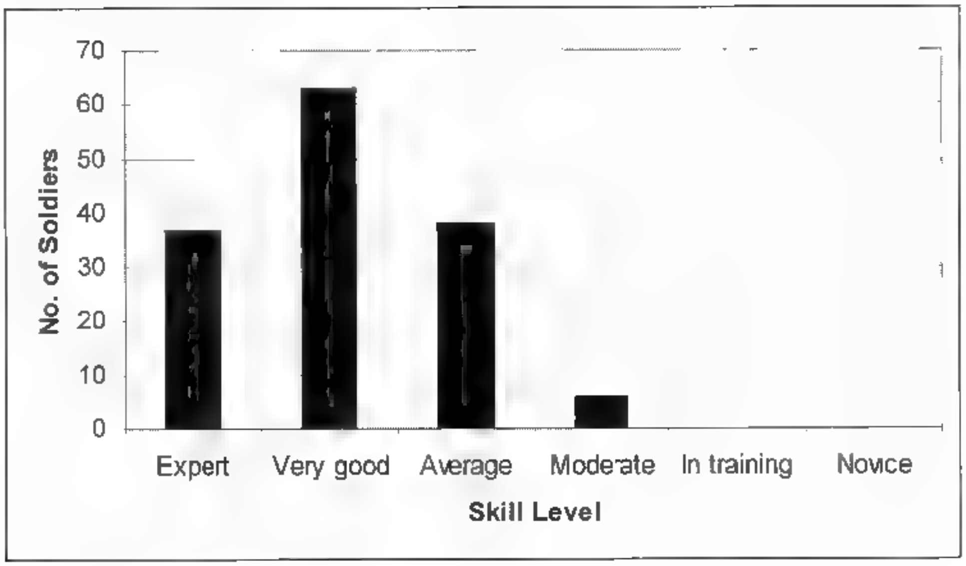


Figure D-5. Compared to others in your company, rate your skill at the alternator replacement task



APPENDIX E: BATTERY CHANGE FREQUENCY & SKILL RATING

Figure E-1. Battery change task frequency

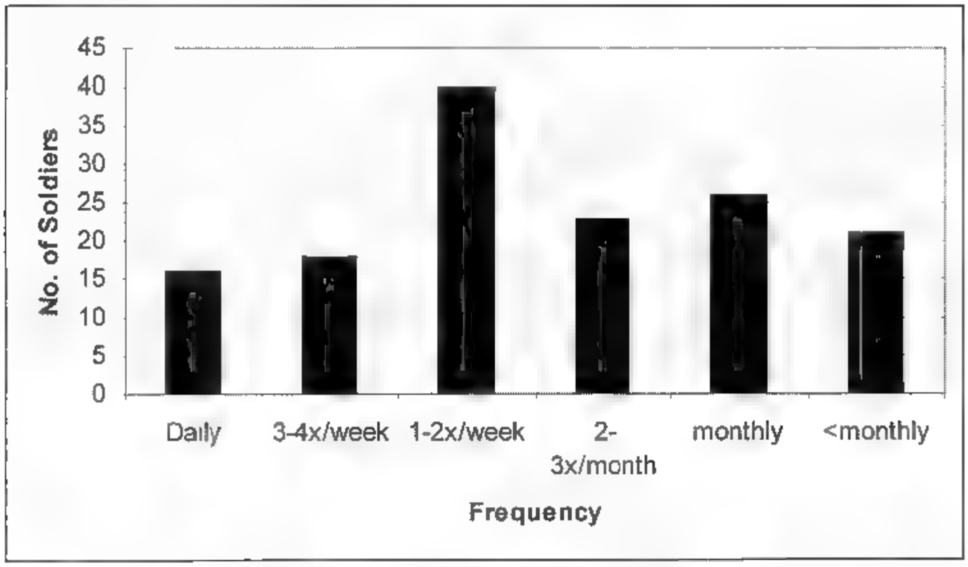


Figure E-2. Most recent battery change task performance

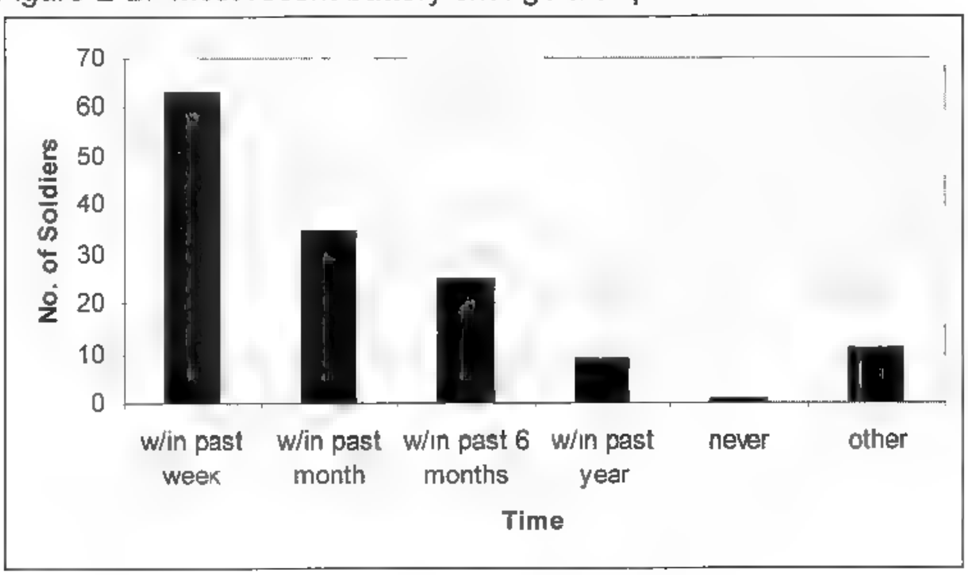


Figure E-3. Battery change pre-task self rating

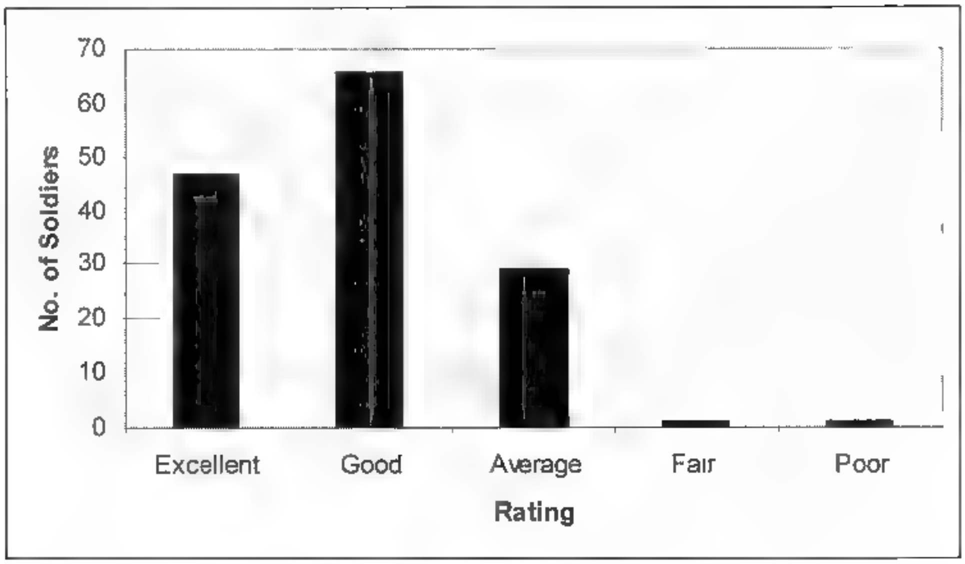


Figure E-4. Battery change post-task performance self rating

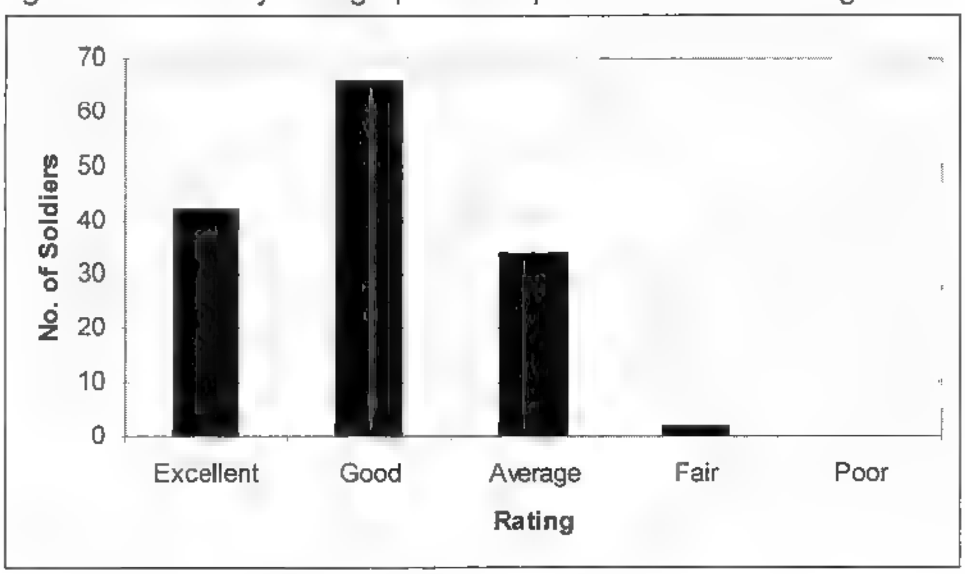
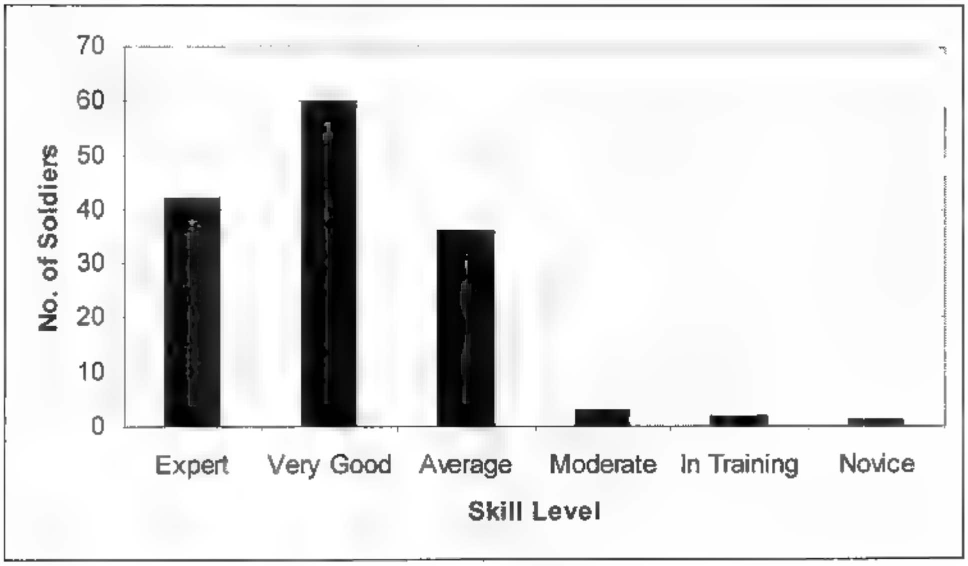


Figure E-5. Compared to others in your company, rate your skill at the battery change task



APPENDIX F: STARTER REPLACEMENT FREQUENCY & SKILL RATING

Figure F-1. Starter replacement task frequency

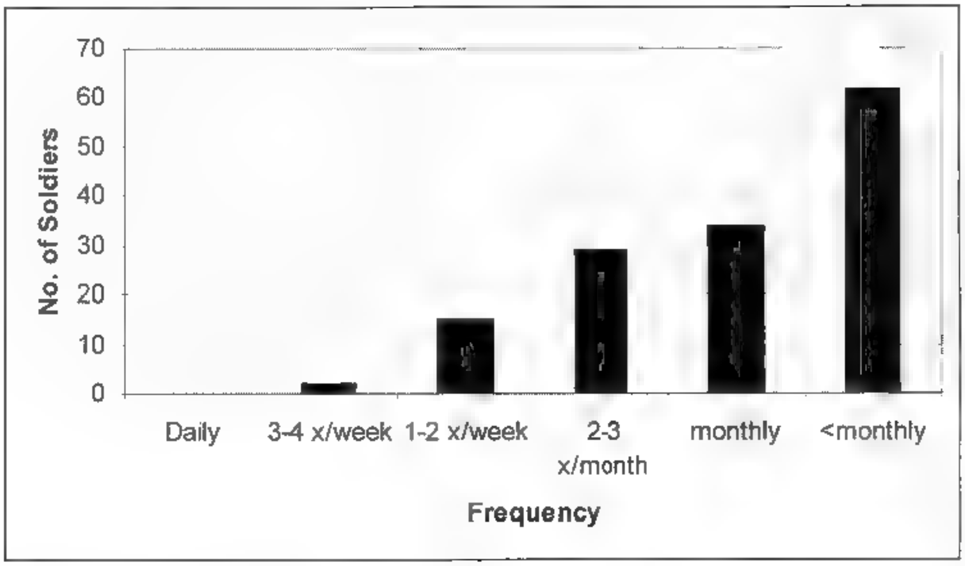


Figure F-2. Most recent starter replacement task performance

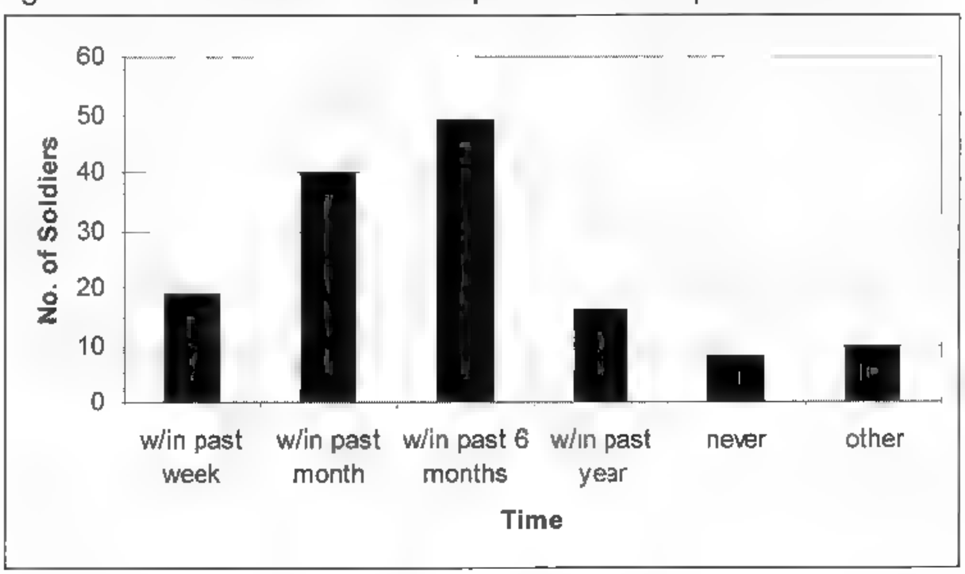


Figure F-3. Starter replacement pre-task self rating

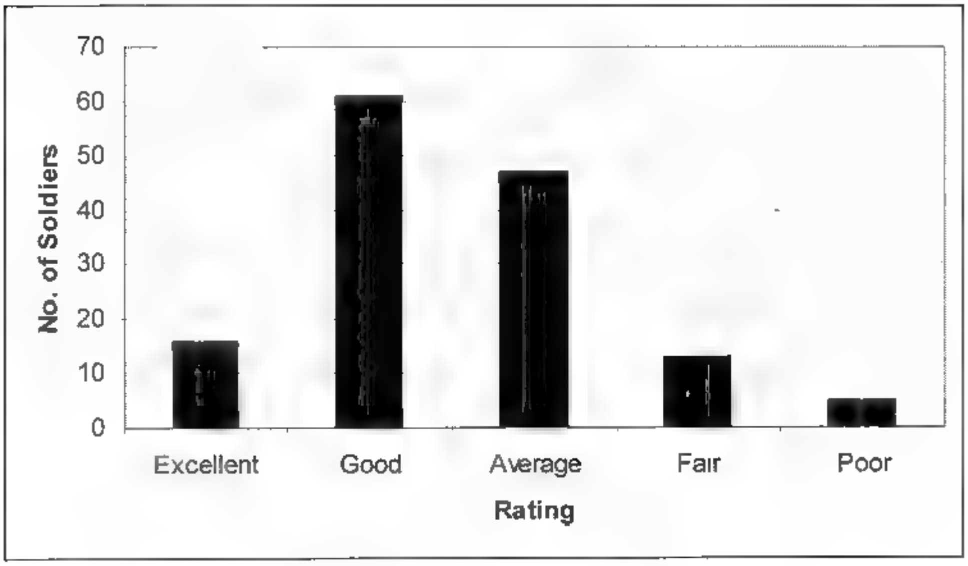


Figure F-4. Starter replacement post-task performance self rating

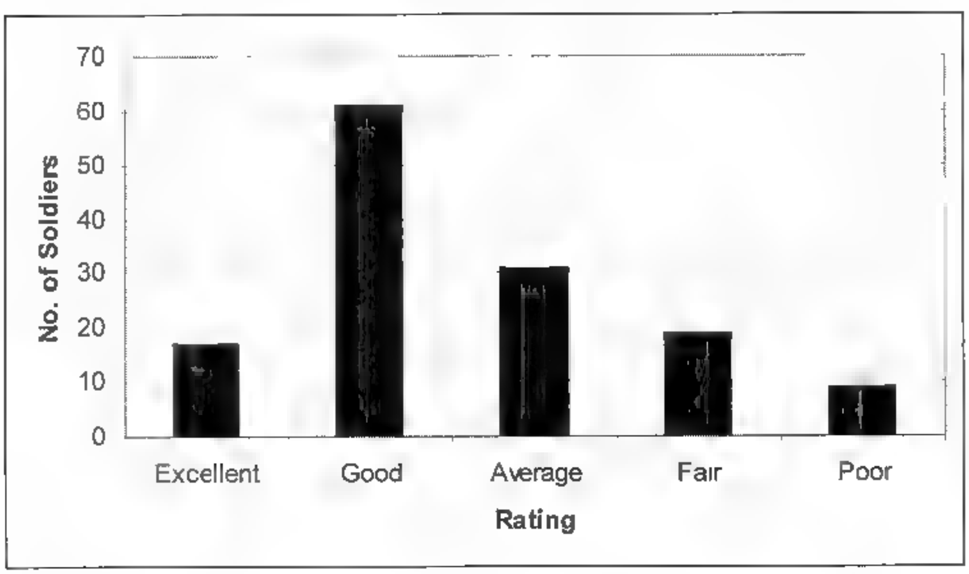
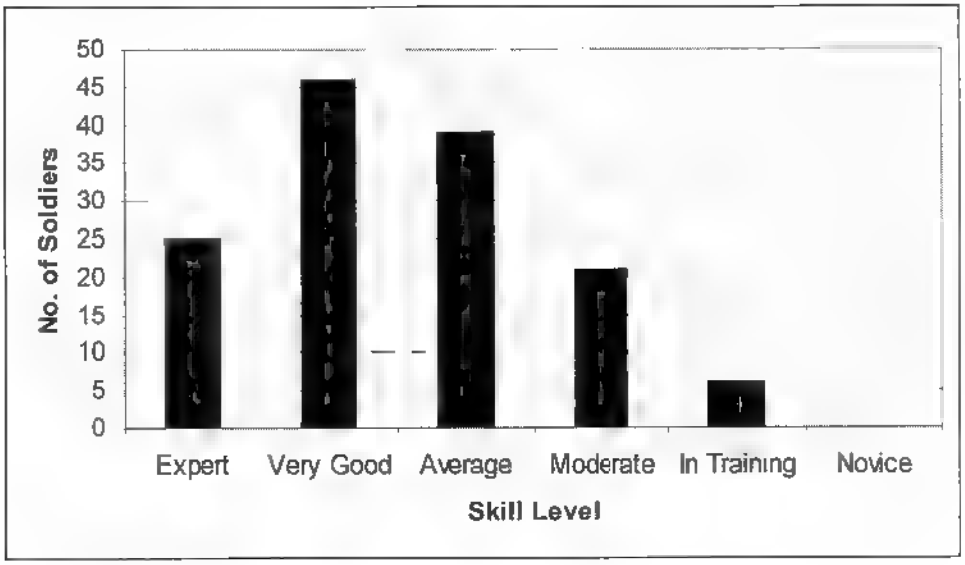


Figure F-5. Compared to others in your company, rate your skill at the starter replacement task



APPENDIX G: TIRE CHANGE FREQUENCY & SKILL RATING

Figure G-1. Tire change task frequency

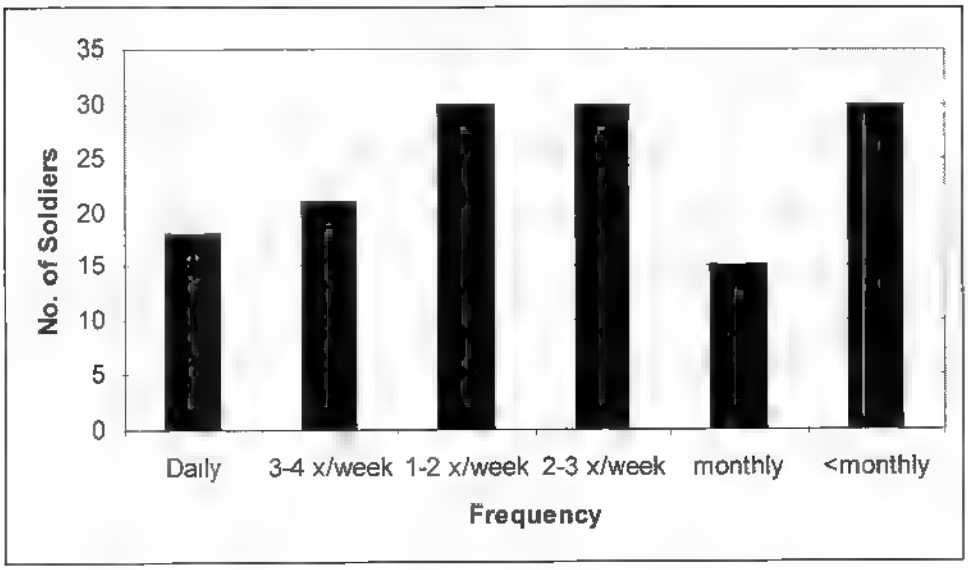


Figure G-2. Most recent tire change task performance

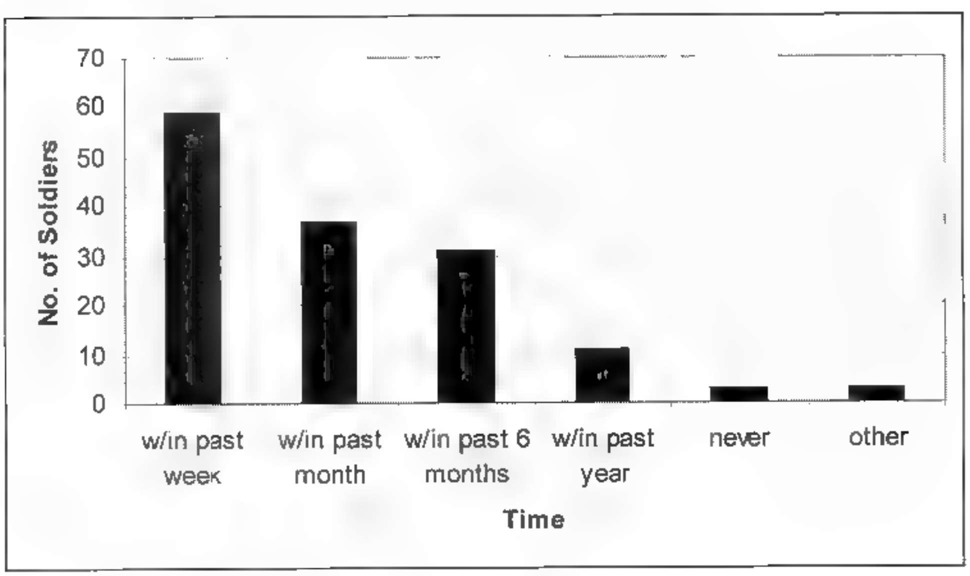


Figure G-3. Tire change pre-task self rating

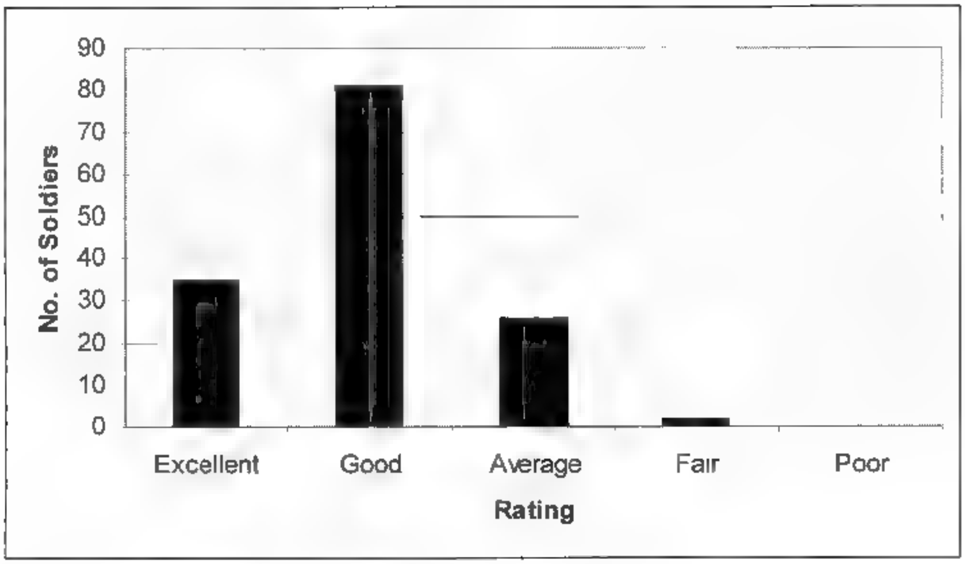


Figure G-4. Tire change post-task performance self rating

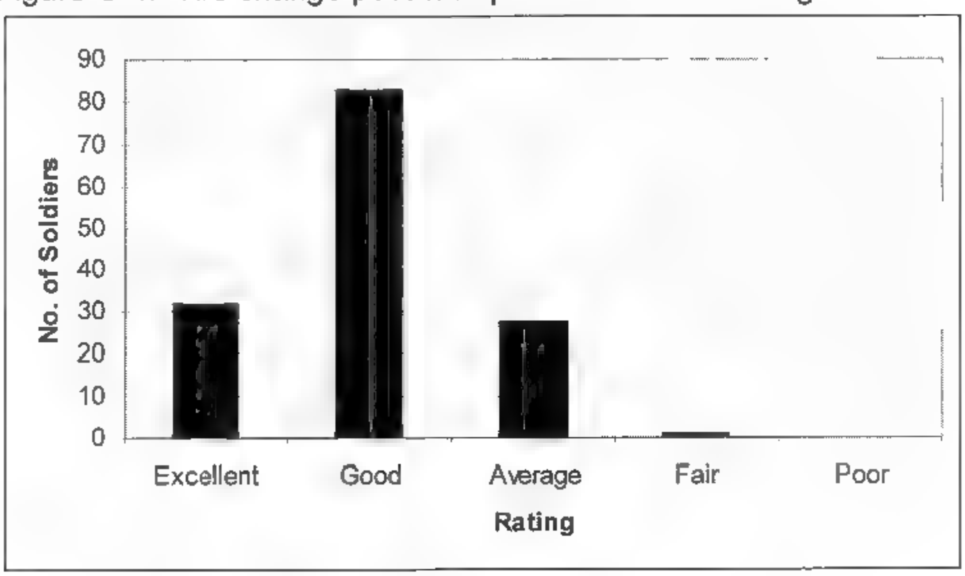
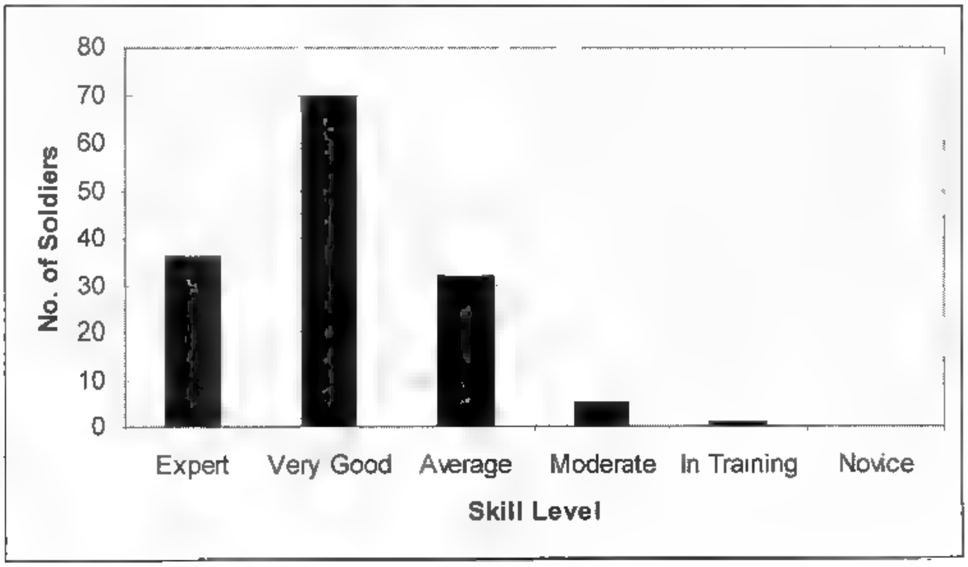


Figure G-5. Compared to others in your company, rate your skill at the tire change task



APPENDIX H: MOS PHYSICAL DEMANDS QUESTIONNAIRE RESULTS

Figure H-1. During the past 12 months, how often have you been unable to perform the full range of your duties because of a work-related over-exertion injury?

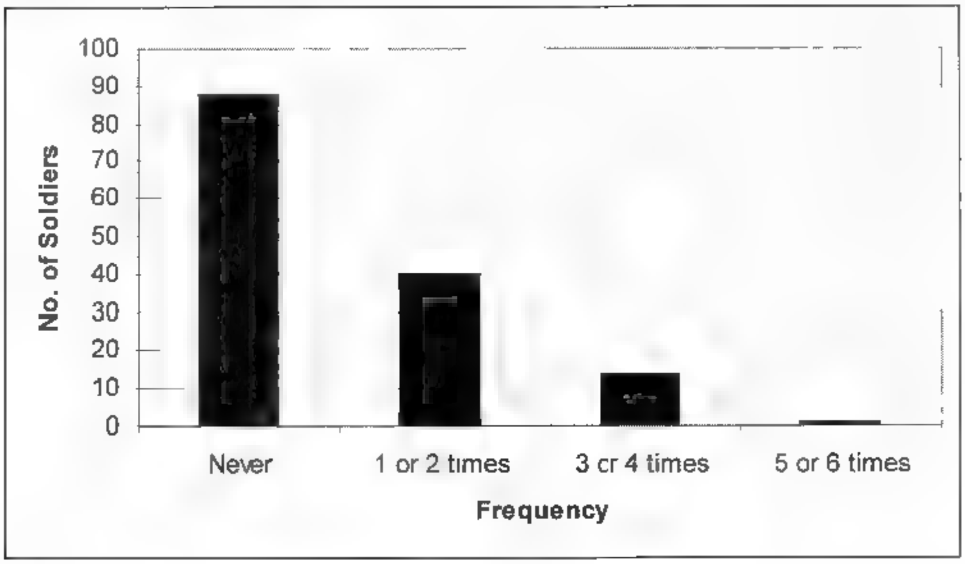


Figure H-2. During the past 12 months, how have over-exertion injuries affected your ability to perform your job?

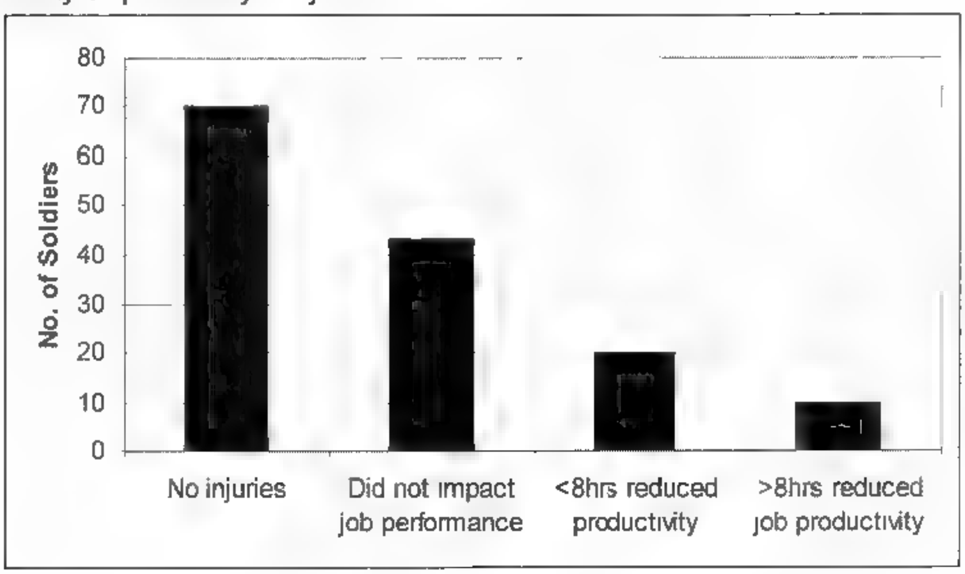


Figure H-3. During the past 12 months, how much additional work were you or your co-workers expected to perform because another co-worker experienced an over-exertion injury?

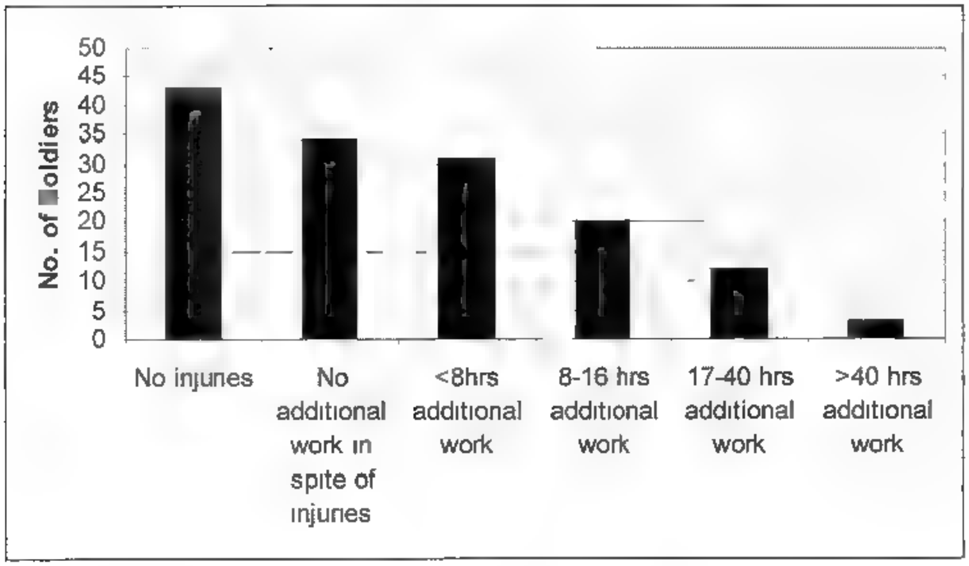


Figure H-4. During the past 12 months of working on the job, how many times did you lack the physical strength or endurance to complete a physically demanding individual task?

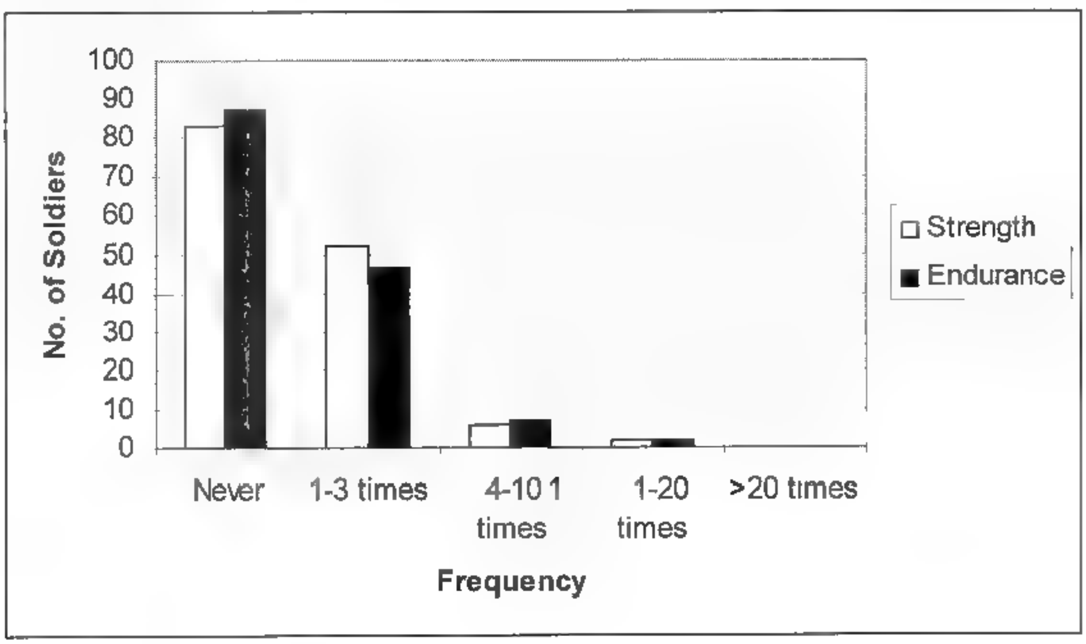


Figure H-5. During the past 12 months, what impact has lack of physical strength or endurance had on your ability to perform strength demanding work tasks?

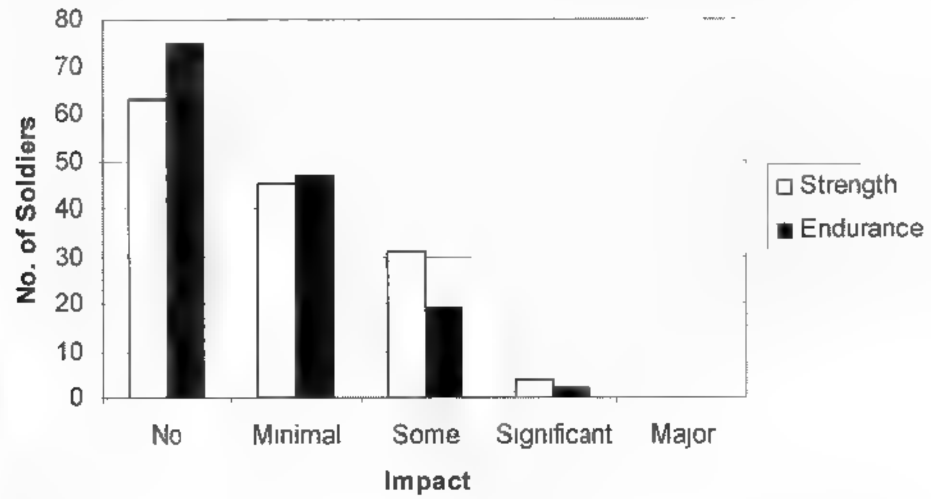


Figure H-6. What generally happened if you lacked the physical strength or endurance to perform a physically demanding individual task?

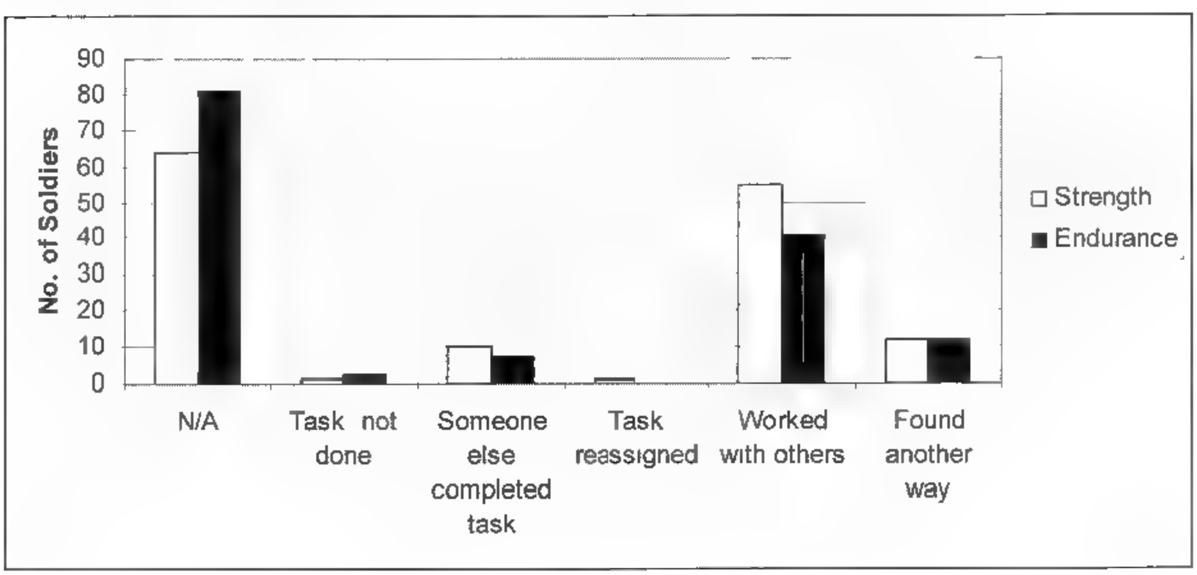


Figure H-7. Most of the time I have adequate strength to get the job done.

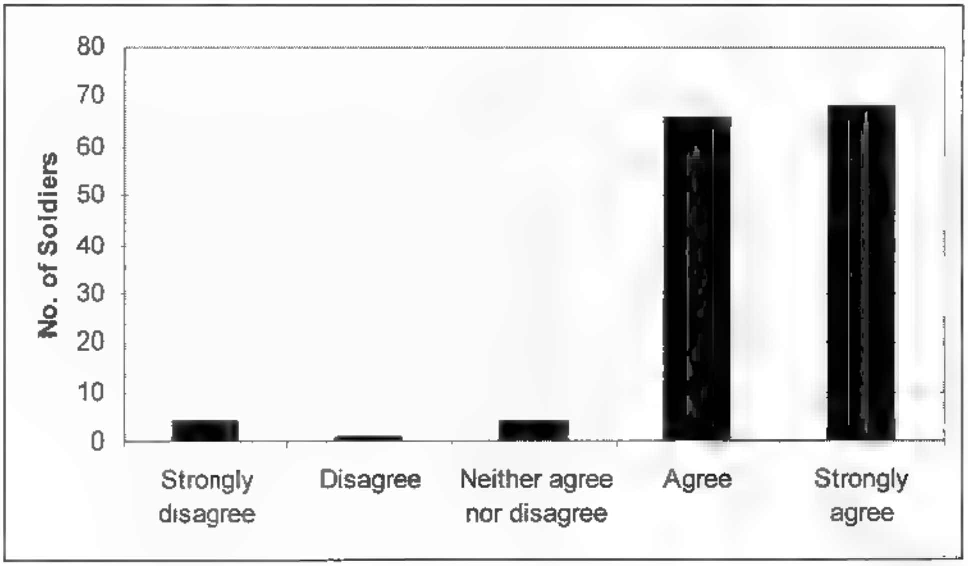


Figure H-8. Lack of physical strength in our work team rarely keeps us from successfully performing our mission.

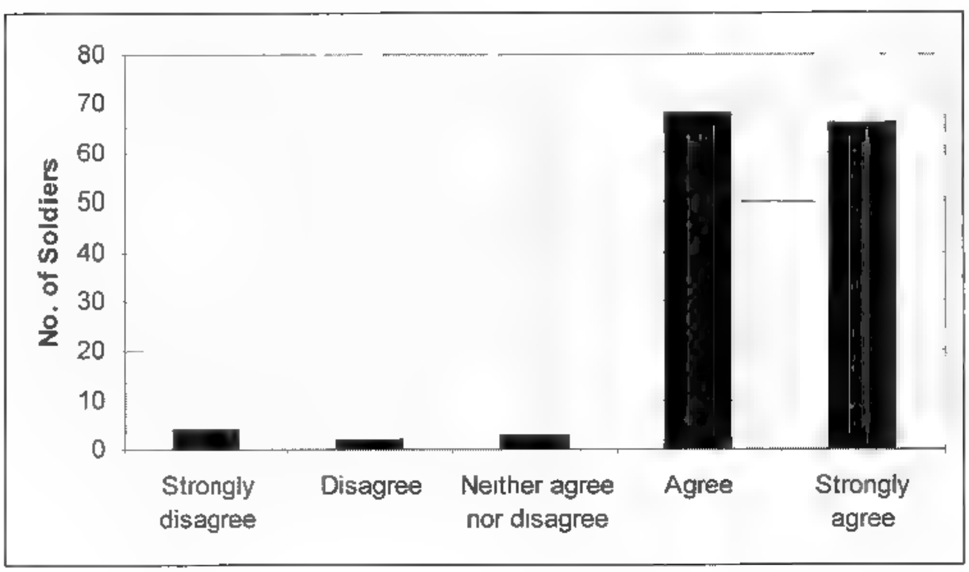


Figure H-9. Most of the time I have adequate endurance to get the job done.

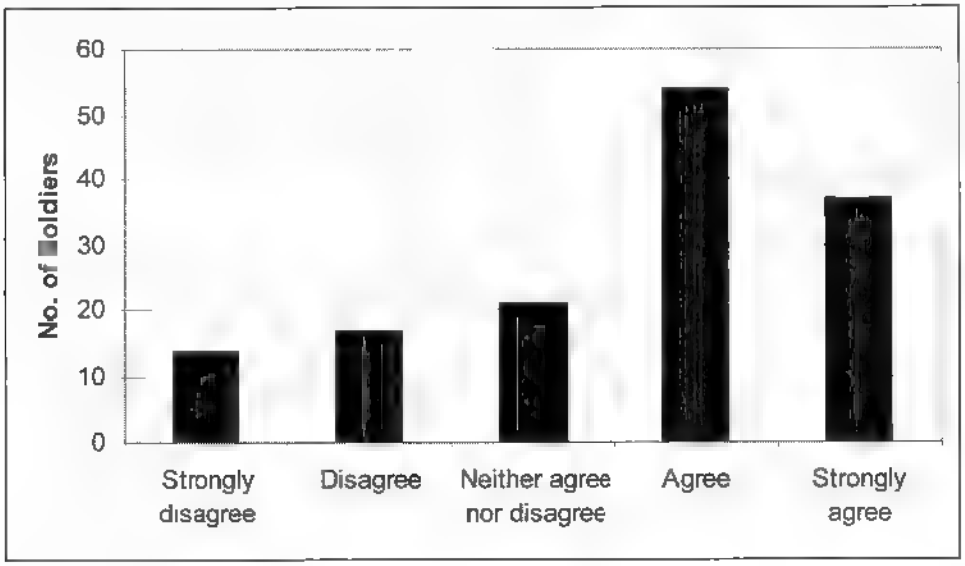


Figure H-10. Lack of endurance in our work team rarely keeps us from successfully performing our mission.

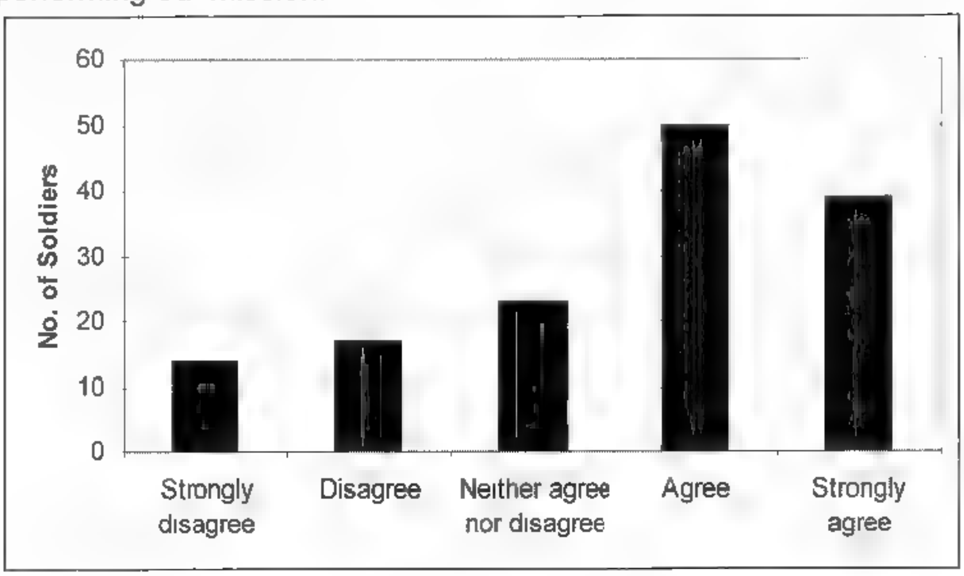
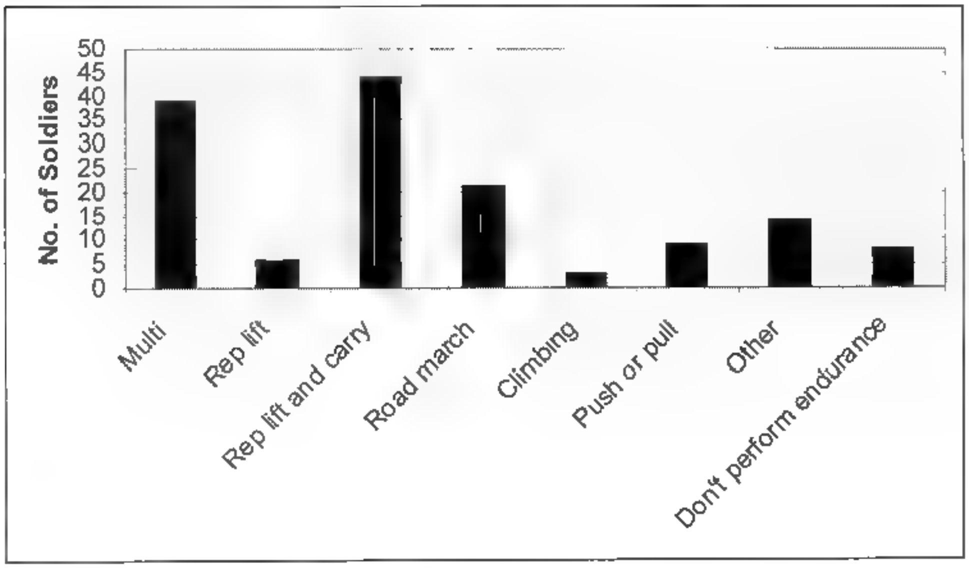


Figure H-11. What types of tasks do you perform as part of your job that leave you especially winded or tired?



APPENDIX I: CORRELATIONS BETWEEN DESCRIPTIVE VARIABLES, PHYSICAL ACTIVITY QUESTIONNAIRE RESPONSES AND TASK COMPONENTS

Table 33. Correlations between descriptive variables and the alternator replacement task components

Variable	Alternator Replacement Removal Time	Alternator Replacement Install Time	Alternator Replacement Total Time Exclude Rest
Age	**-.31**	**-.29**	**-.31**
Rank	**-.34**	**-.29**	**-.32**
Time in MOS	**-.41**	**-.33**	**-.38**
Height	-.17	-.15	-.18
Weight	**-.19**	**-.22**	**-.23**
Lean + BMC	-.15	**-.20**	**-.20**
% Body Fat	-.12	-.12	-.12
IDL 1RM	-.09	-.12	-.12
Bench Press 1RM	-.06	-.11	-.10
Hand Grip Mean	-.11	-.13	-.14
Back Ext Mean	-.05	-.05	-.05
Elbow Ext R Mean	**-.24**	**-.21**	**-.23**
Elbow Ext L Mean	**-.25**	**-.22**	**-.24**
Elbow Flex R Mean	.11	-.02	.02
Elbow Flex L Mean	.08	-.03	-.03
Shoulder Flexion Mean	.11	.02	.04
Leg Ext R Mean	-.16	**-.17**	**-.18**
Leg Ext L Mean	-.12	**-.19**	**-.18**
Leg Flex R Mean	-.02	-.04	-.04
Leg Flex L Mean	-.06	-.11	-.10
Sit-up	.10	.11	.11
Push-up	.09	.16	.15

Marked (Bolded) correlations are significant at $p < .050$.

Table 34. Correlations between descriptive variables and the battery change task components

Variable	Battery Change Removal Time	Battery Change Install Time	Battery Change Total Time Exclude Rest
Age	-.27	-.26	**-.27**
Rank	**-.36**	**-.34**	**-.36**
Time in MOS	**-.30**	**-.27**	**-.29**
Height	**-.21**	**-.20**	**-.21**
Weight	**-.24**	**-.26**	**-.27**
Lean + BMC	**-.24**	**-.23**	**-.24**
% Body Fat	-.06	-.15	-.13
BenchPress1RM	**-.23**	-.16	**-.19**
IDL1RM	**-.28**	**-.21**	**-.24**
Hand Grip Mean	**-.29**	**-.25**	**-.26**
Back Ext Mean	**-.26**	**-.22**	**-.25**
Elbow Ext R Mean	**-.27**	-.14	-.19
Elbow Ext L Mean	**-.28**	-.15	**-.20**
Elbow Flex R Mean	**-.24**	**-.25**	**-.26**
Elbow Flex L Mean	**-.28**	**-.27**	**-.29**
Shoulder Flex Mean	**-.23**	**-.27**	**-.27**
Leg Ext R Mean	**-.21**	-.17	-.19
Leg Flex R Mean	-.11	-.10	-.11
Leg Ext L Mean	**-.23**	-.17	-.20
Leg Flex L Mean	-.13	-.13	-.14
Sit-up	.14	.15	.16
Push-up	-.03	.09	.05

Marked (Bolded) correlations are significant at $p < .050$.

Table 35. Correlations between descriptive variables and the starter replacement task components

Variable	Starter Replacement Removal Time	Starter Replacement Install Time	Starter Replacement Total Time Exclude Rest
Age	**-.19**	**-.24**	**-.25**
Rank	**-.30**	**-.30**	**-.33**
Time in MOS	**-.23**	**-.32**	**-.32**
Height	-.08	-.17	-.14
Weight	**-.19**	**-.27**	**-.27**
Lean + BMC	-.16	**-.28**	**-.26**
%Body Fat	-.13	.09	-.11
Bench Press 1RM	-.06	**-.22**	**-.19**
IDL 1RM	**-.19**	**-.25**	**-.27**
Hand Grip Mean	-.11	-.17	-.17
Back Ext Mean	-.05	-.16	-.13
Elbow Ext R Mean	**-.22**	**-.33**	**-.32**
Elbow Ext L Mean	**-.27**	**-.34**	**-.35**
Elbow Flex R Mean	-.05	-.05	-.09
Elbow Flex L Mean	-.09	-.02	-.08
Shoulder Flex Mean	-.08	-.11	-.11
Leg Ext R Mean	-.14	**-.19**	**-.17**
Leg Ext L Mean	**-.19**	**-.26**	**-.26**
Leg Flex R Mean	-.11	**-.19**	-.11
Leg Flex L Mean	-.12	**-.24**	**-.22**
Sit-up	.02	.06	.06
Push-up	.07	.08	.08

Marked (Bolded) correlations are significant at $p < .050$

Table 36. Correlations between descriptive variables and the tire change task components

Variable	Tire Change Removal Time	Tire Change Install Time	Tire Change Total Time Exclude Rest
Age	**-.23**	**-.20**	**-.20**
Rank	**-.30**	**-.29**	**-.30**
Time in MOS	**-.30**	**-.25**	**-.26**
Height	**-.15**	**-.18**	**-.22**
Weight	**-.29**	**-.22**	**-.24**
Lean + BMC	**-.33**	**-.23**	**-.26**
% Body Fat	.03	-.02	-.01
Bench Press 1RM	**-.22**	-.15	**-.18**
IDL 1RM	**-.36**	**-.30**	**-.33**
Back Ext Mean	**-.33**	**-.29**	**-.31**
Elbow Ext R Mean	**-.31**	**-.21**	**-.24**
Elbow Ext L Mean	**-.36**	**-.22**	**-.27**
Elbow Flex R Mean	-.07	-.15	-.13
Elbow Flex L Mean	-.10	-.15	-.14
Shoulder Flex Mean	-.14	-.20	-.19
Leg Ext R Mean	**-.36**	**-.29**	**-.31**
Leg Ext L Mean	**-.36**	**-.28**	**-.31**
Leg Flex R Mean	**-.25**	**-.19**	**-.21**
Leg Flex L Mean	**-.24**	**-.18**	**-.20**
Sit-up	.07	.06	.06
Push-up	-.05	.01	-.01

Marked (Bolded) correlations are significant at $p < .050$.

Table 37. Correlations between subjective variables and alternator replacement task components

Variable	Alternator Replacement Removal Time	Alternator Replacement Install Time	Alternator Replacement Total Time Exclude Rest
Aerobic DP wk	.09	.15	.14
Aerobic Time PD	-.02	.03	-.01
Strength DP wk	.05	.14	.13
Strength Time PD	.09	.18	.17
Sports Days P wk	-.04	.05	.03
Sports Time PD	-.04	.05	.03
Overall PA	-.06	-.09	-.09
Unable to perform duties	-.15	-.07	-.09
Over exertion injuries	-.20	-.04	-.09
Additional work	**-.28**	**-.24**	**-.27**
Lack physical strength	-.05	-.07	-.07
Impact lack physical strength	.03	.06	.05
Result lack physical strength	.06	.08	.08
Lack endurance	-.14	-.10	-.11
Impact lack endurance	-.07	-.07	-.07
Result lack endurance	.01	.03	.02
Adequate endurance	-.01	-.01	-.01
Get job done	-.06	-.05	-.05
Lack work team	-.07	-.04	-.05
Lack endurance work team	-.01	-.01	-.01

Marked (Bolded) correlations are significant at $p < .050$.

Table 38. Correlations between subjective variables and battery change task components

Variable	Battery Change Removal Time	Battery Change Install Time	Battery Change Total Time Exclude Rest
Aerobic DP wk	-.05	-.02	-.03
Aerobic Time PD	-.11	.01	-.04
Strength DP wk	.08	.12	.11
Strength Time PD	-.05	-.0	-.03
Sports Days P wk	.01	.09	.07
Sports Time PD	-.05	.08	.04
Overall PA	.06	.01	.03
Unable to perform duties	-.11	-.18	-.16
Over exertion injuries	-.07	-.11	-.10
Additional work	-.22	-.16	**-.19**
Lack physical strength	.06	-.01	.01
Impact lack physical strength	.01	-.03	-.02
Result lack physical strength	.13	.08	.10
Lack endurance	-.05	.01	-.02
Impact lack endurance	-.05	-.01	-.02
Result lack endurance	.05	.05	.05
Get job done	-.04	.04	.01
Lack work team	-.01	.01	.01
Adequate endurance	-.02	-.04	-.03
Lack endurance work team	-.10	-.06	-.08

Marked (Bolded) correlations are significant at $p < .050$.

Table 39. Correlations between subjective variables and starter replacement task components

Variable	Starter Replacement Removal Time	Starter Replacement Install Time	Starter Replacement Total Time Exclude Rest
Aerobic DP wk	.04	.09	.08
Aerobic Time PD	-.02	.01	.01
Strength DP wk	.13	.03	.07
Strength Time PD	.08	.09	.10
Sports Days P wk	-.02	-.01	-.01
Sports Time PD	-.01	.04	.03
Overall PA	.01	.06	.06
Unable to perform duties	-.04	-.06	-.06
Over exertion injuries	-.05	-.07	-.07
Additional work	-.17	**-.23**	**-.23**
Lack physical strength	.01	.06	.04
Impact lack physical strength	.05	.09	.07
Result lack physical strength	.05	.13	.13
Lack endurance	.06	.05	.06
Impact lack endurance	.01	.05	.04
Result lack endurance	.17	.05	.06
Get job done	.05	.05	.05
Lack work team	.01	.07	.06
Adequate endurance	-.09	.09	.05
Lack endurance work team	-.02	.06	.05

Marked (Bolded) correlations are significant at $p < .050$.

Table 40. Correlations between subjective variables and tire change task components

Variable	Tire Change Removal Time	Tire Change Install Time	Tire Change Total Time Exclude Rest
Aerobic DP wk	.10	.07	.08
Aerobic Time PD	-.04	-.03	-.03
Strength DP wk	.20	.23	.23
Strength Time PD	-.05	-.01	-.01
Sports Days P wk	-.01	-.04	-.03
Sports Time PD	-.16	-.12	-.13
Overall PA	-.05	-.09	-.08
Unable to perform duties	-.11	-.07	-.09
Over exertion injuries	-.08	-.05	-.06
Additional work	-.22	-.21	-.22
Lack physical strength	.10	.09	.10
Impact lack physical strength	.15	.09	.11
Result lack physical strength	.18	.19	.19
Lack endurance	.12	.06	.08
Impact lack endurance	.11	.06	.08
Result lack endurance	.12	.13	.13
Get job done	.01	.03	.02
Lack work team	-.05	-.01	-.01
Adequate endurance	-.05	-.08	-.07
Lack endurance work team	.06	.01	.02

Marked (Bolded) correlations are significant at $p < .050$.